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DIZZINESS AND FALLS RATE CHANGES AFTER ROUTINE CATARACT SURGERY AND THE INFLUENCE OF VISUAL AND REFRACTIVE FACTORS

DIZZINESS AND FALLS RATE CHANGES AFTER ROUTINE CATARACT SURGERY

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ABSTRACT

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Dizziness and falls rate changes after routine cataract surgery and the influence of visual and refractive factors

Keywords: cohort study, dizziness handicap inventory, older adults, multifocals, spectacle magnification, astigmatism, anisometropia, activity levels, visual acuity.

Purpose: To determine whether symptoms of dizziness and fall rates change due to routine cataract surgery and to determine the influence of visual and refractive factors on these common problems in older adults.

Methods: Self-reported dizziness and falls were determined in 287 subjects (mean age of 76.5±6.3 years, 55% females) before and after routine cataract surgery for the first (81, 28%), second (109, 38%) and both eyes (97, 34%). Six-month falls rates were determined using self-reported retrospective data. Dizziness was determined using the short-form of the Dizziness Handicap Inventory.

Results: The number of patients with dizziness reduced significantly after cataract surgery (52% vs. 38%; $\chi^2 = 19.14$, $p<0.001$), but the reduction in number of patients who fell in the 6-months post surgery was not significant (23% vs. 20%; $\chi^2 = 0.87$, $p=0.35$). Multivariate logistic regression analyses found significant links between post-operative falls and change in spectacle type (increased risk if switched into multifocal spectacles). Post-operative dizziness was associated with changes in best eye visual acuity and changes in oblique astigmatic correction.

Conclusions: Dizziness is significantly reduced by cataract surgery and this is linked with improvements in best eye visual acuity, although changes in oblique astigmatic correction increased dizziness. The lack of improvement in falls rate may be associated with switching into multifocal spectacle wear after surgery.

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This thesis is dedicated to those whom I owe the most for their unconditional love and continuous support.

Parents **Ibrahim and Sada**

Husband **Atiq**

Brother and Sister-in-Law **Enes and Rachel**

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CHAPTER 1

AIMS, OBJECTIVES AND BACKGROUND OF THE STUDY

1.1. Background

Many studies have indicated that over a third of healthy adults (aged 65 years and over) living independently in the community, fall at least once a year with up to half of these individuals experiencing multiple falls (Nevitt, Cummings and Hudes, 1991, Tinetti et al., 1995, Ivers et al., 1998, Lord et al., 2007). The annual falls rate increases to 45% in the over 75 age group (Wojszel and Bien, 2004) and 60% for those aged 90 years and over (Fleming et al., 2008). Falls occur more often in nursing homes, with up to 60% of care home residents reporting at least one fall per year (Rubinstein, Josephson and Robbins, 1994, Lord et al., 2003). This increased rate of falls in the nursing home population is likely to be due to them being older, more frail, having higher levels of chronic illnesses and/or cognitive impairment, and having greater limitations in their mobility than their community-dwelling counterparts (Rubinstein, Josephson and Robbins, 1994).

Falls are the leading cause of deaths in the elderly (over 65) in the European region (Sethi et al., 2006). The most serious fall-related injury is fracture of the hip. Fortunately, hip fractures occur in only 1-2% of falls; however, hip fractures can have severe consequences with the one year mortality rate following hip fractures being 25% (Braithwaite, Col and Wong, 2003). In the elderly population approximately 55-65% of falls result in only minor physical injuries such as abrasions and bruising (Nevitt, Cummings and Hudes, 1991, Tinetti et al., 1995). However, regardless of the degree of injury following a fall, a resultant fear of falling can lead elderly people to self impose restrictions on their functional activities (Vellas et al., 1997, Murphy, Williams and Gill, 2002, Fletcher and Hirdes, 2004) which in turn has both physical and psychological consequences, such as, reduced mobility, social isolation, loss of independence, depressive symptoms and an overall reduction in their quality of life (Legters., 2002, Scheffer et al., 2008).

Visual impairment has been found to be an important risk factor for falls in the elderly (Ivers et al., 1998, Klein et al., 2003). Refractive errors and cataracts are the most common reversible causes of visual impairment in the elderly (Evans and Rowlands., 2004). Numerous studies have shown that adaptive gait and postural stability are significantly worse with refractive blur and cataract simulations (Anand et al., 2003, Heasley et al., 2005). These studies have suggested that falls could be reduced by updating spectacles and performing cataract surgery on elderly people at risk of falls.

However, although two open-design intervention studies of cataract surgery found a significant reduction in falls rates after cataract surgery (Brannan et al., 2003, To et al., 2014), studies including control groups did not reach the same conclusions (Harwood et al., 2005, Foss et al., 2006, McGwin et al., 2006). McGwin and colleagues (2006) reported no difference in falls rate (risk ratio 0.96, 95% CI 0.64-1.42) between a cataract surgery group (n=122) and a control group (n=92). Another study conducted by Harwood and colleagues (2005) conducted a randomised controlled trial (RCT) and reported similar falls rate after surgery in the first-eye cataract surgery group and the control group. Foss and colleagues (2006) conducted a randomised controlled trial of second-eye cataract surgery patients. The rate of falling was reduced in the operated group however, it was not statistically significant (rate ratio 0.68, 95% CI 0.39-1.19, P=0.18). Later chapters provide a more detailed discussion of these important studies.

The results from large-scale assessments of the effect of cataract surgery on injurious falls have also shown indefinite results. A retrospective cohort study conducted by Meuleners and colleagues (2014) found a significant 34% increase in injurious falls that required hospitalisation in the two years after bilateral cataract surgery compared with the two years before first-eye cataract surgery (RR 1.34, 95% CI 1.16-1.55). Tseng and colleagues (2012) reported a reduction in the odds of hip fracture after cataract surgery. The incidence of hip fracture in the cataract surgery group was 1.3% and 1.2% in the cataract diagnosis group. This study found a 16% reduction in the adjusted odds of hip fracture in the cataract surgery group compared with the cataract diagnosis group. Chapter five provides a more detailed discussion of these studies.

The results from studies looking into the effect of vision intervention on the rate of falls have shown different findings. Cumming and colleagues (2007) conducted a RCT in which a group of 616 community dwellers aged 70 years and over, were randomised to either a control group (n= 307) or an intervention group (n= 309) and prospectively followed up to collate data on falls and fractures they experienced in a 12-month period. The intervention group received the recommended refractive correction. The control group were left to their usual care. During the 12 month follow up period, it was observed that falls occurred significantly more often in the intervention group (65% fell at least once) than in the control group (50% fell at least once). The falls rate ratio was 1.57 (95% CI 1.20-2.05, P=0.001). Furthermore, there were more fractures in the intervention group (n=31) compared to the control group (n=18). The relative risk was 1.74, 95% CI 0.97-3.11, P=0.06. The authors suggested that the subjects in the intervention group might have had difficulty adapting to significant changes in refractive condition during the first few weeks of wearing new spectacles as the full refractive correction was prescribed in all cases (Cumming et al., 2007). This study has been discussed in more detail in chapter five.

In this study, dizziness was also included as a principal outcome measure. Dizziness is highly prevalent in the elderly population (Yardley et al., 1998, Tinetti, Williams and Gill, 2000) and may be increased with poor vision (Colledge et al., 1996, Stevens, 2008, Gomez et al., 2011) and is linked with falls (Tinetti et al., 2000, Black and Wood, 2005, Rubenstein, 2006, Menant et al., 2013, Moller et al., 2013). This is the first study evaluating the effect of cataract surgery on the symptoms of dizziness.

1.2. Aims of the Study

We hypothesise that there are some factors associated with cataract surgery that lead to a relatively greater risk of falling and increased dizziness, which may in some circumstances, balance the reduction in falls risk and dizziness due to improvements in visual function. In this way, changes in falls rate due to cataract surgery may not be as large as might be expected.

The aims of this study were to determine whether these factors (listed below) had a significant effect on post-operative fall rates and symptoms of dizziness:

(i) Adaptation problems to large changes in refractive correction (Cumming et al., 2007).

(ii) Increased anisometropia after first eye cataract surgery (Meuleners, 2014).

(iii) Refractive magnification changes increasing the risk of trips on steps and stairs (Elliott and Chapman, 2010).

(iv) Changes in spectacle type pre and post surgery (Haran et al., 2010).

(v) Increased confidence leading to greater outdoor activity leading to increased falls rate (Cumming et al., 2007).

1.3. Structure of the Thesis

This thesis begins with a review of the literature regarding the incidence, risk factors and consequences of falling in older people. This is then followed by a discussion on the prevalence, classification, risk factors, signs and symptoms and the treatments available for age-related cataract.

The fourth chapter reviews the literature on the prevalence of visual impairment and its implications as a risk factor for falling. As mentioned above, numerous studies have suggested that falls can be reduced by updating spectacles and performing cataract surgeries. Chapter Five reviews the available literature on the same.

Chapter Six discusses the prevalence, risk factors and causes of dizziness, paying particular attention to the literature regarding poor vision and its implications for dizziness and its link with falls.

Chapter Seven provides a detailed description of the methodology used in the present study. Within this chapter inclusion and exclusion criteria are explained in addition to how various aspects of data relating to demographics, medical issues, vision, falls and dizziness were collected. It describes the ethical considerations undertaken for this study including; ethical approval needed for this study (granted by the National Research Ethics Service (NRES) Committee of the East of England), the required consent from the participants and the confidentiality issues in connection with the handling of participants' personal data.

The results of this study are presented in Chapter Eight, along with a detailed description and explanation of the statistical analysis used for the interpretation of the falls and dizziness data. The outcome of the results are discussed and evaluated in Chapter Nine. Finally, Chapter Nine also sets out future plans and reviews the overall aims bringing the thesis to a detailed conclusion.

CHAPTER 2

LITERATURE REVIEW: FALLS IN OLDER PEOPLE

This chapter contains an in depth review of the existing literature surrounding falls in the elderly population, paying particular attention to the incidence of the same, the risk factors and the consequences of its occurrence. However before this review is presented, it is crucial to pay attention to two important methodological considerations relevant to the evaluation and interpretation of the existing research studies on falls, namely, how falls are defined and ascertained.

2.1. Definition of a fall

One commonly used definition of a fall is that provided by the World Health Organisation being, "An event, which results in a person coming to rest inadvertently on the ground or other lower level'' (World Health Organization, 2012).

There are however, many variations of falls definitions used throughout the literature which gives rise to consistency issues and difficulties when trying to analyse findings and recognize trends in the research. Hauer et al. (2006) conducted a systematic review into the definitions used in trials that measured falls as part of their methodology and found that, out of the ninety papers reviewed, approximately half failed to provide a definition of a fall. Reviewing the remainder that had used definitions, they were still unable to find a standard definition. One definition used by 9% of the trials was that provided by the Kellogg International Working Group (1987) defining a fall as, 'unintentionally coming to the ground or some lower level and other than as a consequence of sustaining a violent blow, loss of consciousness and sudden onset of paralysis as in stroke or an epileptic seizure' (Gibson et al., 1987, reviewed in Hauer et al., 2006). Nevitt and colleagues (1991) noted that many of the studies that cited the above definition had made changes to it in some way; for example, some studies varied the description of the level of fall (e.g. ground, floor, furniture contact) whereas others varied the behavioural descriptor of the nature of the fall (e.g. accidental, inadvertent). In addition to this, some studies were excluding certain types of fall as a result of environmental factors e.g. disease related symptoms and acute medical events, such as seizures (reviewed in Hauer et al., 2006).

The absence of a standardised definition makes it difficult to compare fall rates in studies conducted in similar populations (Lamb et al., 2005). Having a clear definition of what denotes a fall is fundamental to researchers studying falls in terms of comparing their own research and for data collection purposes. Many researchers rely on their participants to report falls, therefore a clear definition, simplified in lay persons terms that is easy to understand, is paramount for the participants to refer to when deciding whether or not their experience amounts to a fall within the guidelines of the study.

A consensus statement from the Prevention of Falls Network Europe (ProFaNE; www.profane.eu.org) recommended that a fall should be defined as ''an unexpected event in which the participants come to rest on the ground, floor, or lower level'' (Lamb et al., 2005). Including the lay persons' perspective, ProFaNE suggested that in falls studies all participants should be asked ''have you had any fall including a slip or trip in which you lost your balance and landed on the floor or ground or lower level?''(Lamb et al., 2005).

2.2. Methods used to ascertain falls

Despite the heterogeneity that exists in falls reporting systems, the methods and time periods for collecting data are becoming more uniform across the studies over time, as many researchers are recognising the advantages and disadvantages of these methods in their discussions of the same. According to a systematic review carried out by Hauer et al. (2006) the methods used to ascertain falls can be grouped into three main categories, these are: prospective, retrospective and surveillance/abstraction.

Prospective data collection relies on the participants recording the falls using aids such as postcards, calendars and diaries at weekly or monthly intervals over a specified time, usually 12 months. The contemporaneous logging of the incident usually increases the accuracy of the report made and lowers the risk of bias, as the recall period is a lot shorter than is used in retrospective studies. It is hard to conclude which aid is the most accurate in ascertaining falls given that a number of these are used in conjunction with each other across various studies. However Hauer et al. (2006) did note that studies using falls diaries noted an increase in falls reported compared with studies that did not use the falls diary method. The most likely reason for this is that participants' experienced the observer effect (commonly known as the Hawthorne effect) in which they are more likely to change their behaviour because they are aware they are the participants of an observation study.

In comparison, retrospective falls ascertainment relies on the use of interviews either face to face or over the telephone in addition to postal questionnaires requesting participants' to report falls that have already occurred based on their recollection of the incidents. Relying on participants to recall incidents that may have happened up to twelve months prior to them being asked about the event significantly weakens the potential accuracy of the reports made. This is particularly true for the elderly population, given that there is a higher risk of impaired cognitive functions and memory issues interfering with the accuracy of the recall.

Cummings and colleagues (1988) highlighted issues connected to recall, when they carried out a study to determine the accuracy of falls reporting in a group of 304 community-dwelling participants over the age of 60. Firstly, the participants were prospectively studied via weekly home visits confirming and recording their falls. At the conclusion of the study, the researchers retrospectively tried to obtain the same data via telephone interviews asking the participants to report falls suffered in the preceding three, six or twelve months. When asked twelve months after the baseline examination, if they had fallen in the previous year, 13% of those logged prospectively as having fallen in that time period, failed to recall the fall when asked about the incident retrospectively i.e. after the passage of a longer period of time. The authors concluded from this, that the falls rate data in retrospective studies is likely to be higher than reported in the literature due to elderly participants' having problems recalling the falls. However despite this, it also indicated that the baseline examination acts as a marker to aid participants to recall their falls as many of the participants could remember quite clearly falls that occurred before and after the baseline examination.

Hauer et al. (2006) noted that the least popular method of ascertaining falls was the surveillance/abstraction approach, where researchers collected data either by routine surveillance systems or abstracted the relevant data needed from participants' healthcare records. The main drawback of relying on this approach is the differences in quality and detail in the record keeping across the healthcare establishments recording the falls and also issues of accessibility, in light of the strict rules of confidentiality regarding records and the reluctance of some health authorities to provide permission for researchers to view the same.

In light of the drawbacks of the above method, although very useful, many studies have used this as a secondary way to capture the relevant data in the event that the primary method selected fails to obtain the data needed.

Another source of discrepancy in falls studies is the methods used to summarise falls data. In a review by Hauer and colleagues (2006), the most commonly reported summary statistic was the number of participants sustaining a fall i.e. the number of fallers. The number of falls i.e. incidence of falls was the second most commonly reported summary statistic. On the other hand, the falls rate, expressed as the number of falls per person, was only reported in 28% of the reviewed studies (Hauer et al., 2006). It is important to note when reviewing these studies whether the researchers were collecting data on the rate of falls or fallers (Cumming, Kelsey and Nevitt, 1990). If the rate of falls is the outcome measure, this measure is termed the rate of falls. However, if the number of fallers is the outcome measure, most studies report the percentage of participants that fell in one year (Cumming, Kelsey and Nevitt, 1990). This figure can be easily misunderstood as being the proportion of people who fell in a defined population over a particular time i.e. the period prevalence rate of fallers (Cumming, Kelsey and Nevitt, 1990). However, since falls are point events, they cannot have prevalence. The term incidence of fallers cannot be given to those subjects who fall at least once over the study period, as this could be interpreted as the proportion of new cases occurring in a population, who were initially free of falls (Cumming, Kelsey and Nevitt, 1990). It is most accurate, in this instance, to avoid using epidemiological terminology and just simply state the results (Cumming, Kelsey and Nevitt, 1990).

2.3. Incidence of falling

Many studies have indicated that over a third of healthy adults aged 65 years and over, living independently in the community fall at least once a year, with up to half of these individuals experiencing multiple falls (Nevitt, Cummings and Hudes, 1991, Tinetti et al., 1995, Ivers et al., 1998, Lord et al., 2007). Annual falls rate increases to 45% in the over 75 age group (Wojszel and Bien, 2004) and 60% for those aged 90 years and over (Fleming et al., 2008). Falls occur more often in nursing homes, with up to 60% of care home residents reporting at least one fall per year (Rubinstein, Josephson and Robbins, 1994, Lord et al., 2003). This increased rate of falls in the nursing home population is likely to be due to them being older, more frail, having higher levels of chronic illnesses and/or cognitive impairment, and having greater limitations in their mobility than their community-dwelling counterparts (Rubinstein, Josephson and Robbins, 1994). Falls are therefore more common in frailer elderly; but are not confined to this group alone. A study conducted by Speechley and Tinnetti (1991), identified different types of falls and fallers amongst the elderly population. Their sample consisted of 336 community-dwelling elderly adults. Each participant was assigned to either a ‘frail’, ‘vigorous’ or the ‘transition’ group based on demographics, physical and psychological variables. The frequency of falls in these three groups was ascertained. As one would expect, the incidence of falling in one year follow-up was highest in the frail group at 52% (n=67) and lowest in the vigorous group at 17% (n=15). However, 22% of falls experienced by the vigorous group resulted in serious injury as opposed to only 6% of falls in the frail group. Falls occurring on stairs were more common in the vigorous group (27% versus 6%). Compared with the frail group, the vigorous group were more likely to fall with an environmental hazard present (53% versus 29%). Thus environmental factors may play a greater role than intrinsic factors in the more ‘vigorous’ elderly. The authors suggest this may be because the vigorous individuals venture away from home more often than their frailer counterparts and so are exposed to environmental hazards more frequently. Speechley and Tinetti (1991) concluded that fall-related injuries can be a serious health problem for both vigorous as well as frail elderly individuals. Therefore, fall prevention strategies should be directed to all elderly individuals but need to be tailored to each individual based on their circumstances.

2.4. Falls Location

The location of falls has been found to be related to age, gender and frailty. In community-dwelling older women, the number of falls occurring outside the home decreased with age (Lord et al., 1993). Campbell and colleagues (1990) found that fewer men than women fell inside the home (44% versus 65%) and more men fell in the garden (25% versus 11%). Furthermore, most falls occur during periods of maximum activity in the morning or afternoon, and only about 20% occur between 9pm and 7am (Campbell et al., 1990). Steps, stairs and kerbs are the most common hazards associated with a fall in the older population. In the UK, approximately 290,000 people are seriously injured and over 500 people die every year as a result of a fall on steps or stairs (Wright and Roys, 2005). Injuries are particularly associated with descending stairs, with associated injuries being about three times more frequent then stair ascent injuries (Startzell et al., 2000).

2.5. Consequences of falling

Falls are the second leading worldwide cause of death in the elderly, with an estimate of more than 420,000 people dying each year globally as a result of a fall (World Health Organisation, 2012). Falls are responsible for more than 40% of injury-related deaths in Australia. One per cent of all deaths in Australians aged 65 and over are due to falls (reviewed in Black and Wood, 2005).

Siracuse and colleagues retrospectively reviewed all the falls related admissions to hospital in 2008, for patients aged 75 years and older. In 2008, 708 patients were admitted to Beth Israel Deaconess Medical Centre, Boston, United States as a result of a fall. The short-term-mortality rate, for patients up to 30 days after a fall-related admission to hospital was approximately 6%. The following were all found to be independent predictors ($p<0.05$) of short-term mortality (Siracuse et al., 2012): male sex, atrial fibrillation, acute myocardial infarction, congestive heart failure (CHF), intracranial haemorrhage, Clostridium difficile infection, hospital-acquired pneumonia and intubation.

In the elderly population approximately 55-65% of falls result in only minor physical injuries such as abrasions and bruising (Nevitt, Cummings and Hudes, 1991, Tinetti et al., 1995). In the UK in 1999, there were 204,424 admissions to the hospital for falls-related injuries in adults aged 60 years and over (Schuffham, Chaplin and Legood, 2003).

The most serious fall-related injury is fracture of the hip. Fortunately, hip fractures occur in only 1-2% of falls; however, hip fractures can have severe consequences with the one year mortality rate following hip fractures being 25% (Braithwaite, Col and Wong, 2003). Marottoli and colleagues (1992) analysed the outcomes of 120 patients who suffered a hip fracture over a 6-year period. They found that before their fractures, 86% could dress independently, 75% could walk independently and 63% could climb a flight of stairs. Six months after their hip fractures, these percentages had dropped to 49%, 15%, and 8% respectively. A recent report revealed that the NHS spends £1.7 billion per year treating hip fractures resulting from falls (Lawrence et al., 2005).

2.6. Fear of falling

In addition to physical effects of a fall, many older people experience psychological consequences directly related to the fall. A serious psychological consequence is fear of falling again (Fletcher and Hirdes, 2004). Fear of falling has also been reported amongst the elderly who had not fallen (Legters, 2002). This is of great concern as several epidemiological studies have identified a link between fear of falling and self-imposed restriction of functional activity (Vellas et al., 1997, Murphy, Williams and Gill, 2002, Fletcher and Hirdes, 2004). This activity restriction can over time lead to decreased mobility and independence, social isolation, deteriorating health and depression and reduced quality of life (Legters, 2002, Scheffer et al., 2008). A recent review found the main risk factors for fear of falling are increasing age, being female and having at least one previous fall (Scheffer et al., 2008). The prevalence of fear of falling reported in studies varies from 21 to 85% (Scheffer at al., 2008). This great variation in the reported prevalence of fear of falling in older people is partly due to methodological differences i.e. different tools used to measure fear and possibly due to the lack of standard classification for fear of falling and its consequences. Despite these discrepancies, studies have consistently reported significant prevalence of fear of falling with an associated self-imposed physical activity restriction. Fear of falling is one of the potential modifiable risk factors where there is a need for intervention programmes that might be very effective in the prevention of falls.

2.7. Risk factors for falls

Many risk factors for falls have been identified in the literature. They have been broadly classified into intrinsic and extrinsic factors.

The main intrinsic risk factors for falls that have consistently been reported include increasing age, female gender, history of falls, impaired muscular strength and problems with mobility and poor vision (Tinetti, Speechley and Ginter, 1988, Campbell, Borrie and Spears, 1989, Nevitt et al., 1989, Ivers et al., 1998). The use of certain medications including sedatives, antidepressants and psychotropic medications (Tinetti and Williams, 1998, Landi et al., 2005) in addition to poly-pharmacy (taking four or more medications) has also been identified as increasing the risk of falling (Campbell, Borrie and Spears, 1989, Rubeinstein, Josephson and Robbins, 1994, Cummings et al., 1995). Certain chronic conditions including Parkinson's disease, stroke, cognitive impairment and arthritis are also known risk factors (Tinetti, Speechley and Ginter, 1988, Nevitt et al., 1989).

Epidemiological studies have shown that falls are typically multi-factorial. The more risk factors an individual has the more likely they are to fall. Tinetti and colleagues (1988) found a linear relationship between falls and risk factors ranging from an 8% falls rate with no risk factors to 78% with four or more risk factors.

In addition to the above intrinsic risk factors there are many environmental (extrinsic) risk factors that have been associated with the increased risk of falls. These include the use of inappropriate footwear, poor environmental lighting, obstructed walkways, loose rugs and slippery or uneven surfaces (Nevitt et al., 1989). A review conducted by Nickens (1985), found extrinsic risk factors to be secondary to intrinsic risk factors. The author suggested this could be due to the fact that intrinsic factors become more apparent with age (Nickens, 1985).

2.8. The Ageing Population

The high incidence of falling in the elderly is of great concern due to the increasing size of the elderly population. The UK population aged 65 and over is predicted to increase from 10.3million in 2010 to 12.7million in 2018 (Office for National Statistics, 2011). Growth in this age group is projected to continue for the foreseeable future, with the over 65 population expected to reach 16.9million in 2035 (Office for National Statistics, 2011). In 1985, there were around 690,000 people in the UK aged 85 and over, accounting for 1% of the population. Since then numbers have more than doubled reaching 1.4million in 2010 (2% of the UK population). By 2035 the number of people aged 85 and over is projected to be 2.5 times larger than in 2010, reaching approximately 3.6million and accounting for 5% of the total population (Office for National Statistics, 2011).

Population ageing is a global demographic trend. For example in the United States, in 2010, 40.4 million (13.1%) of Americans were aged 65 years and over, by 2050 this proportion is projected to almost double to 23% and for the 85 years and over group, the relative growth is expected to be even higher (United States Census Bureau, 2010). Due to these changes in population demographics in the UK as well as globally, prevention of falls is an important public health issue that needs to be addressed by all health care professionals.

2.9. Summary

The huge and fast growing increase in the elderly population together with the high incidence and serious consequences of fall for that population in terms of mortality, morbidity and economical and social cost, justify falls as a major public health issue that urgently needs to be addressed. Poor vision has been identified as an important risk factor for falls and remains a fundamental consideration in light of their being scope to improve patients' vision (see Chapter 4).

CHAPTER 3

LITERATURE REVIEW: CATARACTS AND AGE-RELATED EYE DISEASES

This chapter discusses the prevalence, classification, risk factors, signs and symptoms and the treatments available for age-related cataract. It also contains a brief introduction to common age-related eye diseases including age-related macular degeneration (ARMD), glaucoma and diabetic eye diseases which are relevant as some of the study's participants presented these in addition to their cataract.

3.1. Lens transparency

Maurice's lattice theory suggests that the collagen fibres of the cornea are parallel and equal in diameter. The axis of the collagen fibres are arranged in a regular lattice, allowing each row of fibres to act like a diffraction grating (Maurice, 1957). The scattered light from individual fibres interferes destructively in all directions, except that of the incident beam, causing the grating to appear transparent (Maurice, 1957).

The lens fibres are also in a regular lattice arrangement. The light scattering caused by differences in refractive index between the lens fibre membranes and cytoplasm causes the cortex of the lens to appear transparent (Michael et al., 2003).

3.1.1. Light Scatter

There are two types of light scatter: backwards and forwards. Backwards light scatter is the amount of light scattered back from the eye towards the light source, whereas forward light scatter is the light scattered that causes reduced vision due to the forward scattering of light onto the retina.

Light scattering occurs when the spacing between elements of different refractive index become comparable with or greater than the wavelength of light (Wesemann, 1987). In patients with dense cataracts, the number of large particles increases causing more light to scatter towards the retina (i.e. forward light scattering), than in the backward light scatter (Wesemann, 1987).

3.2. Definition of a Cataract

In the literature, there are many variations of what defines a cataract which gives rise to consistency issues and difficulty when trying to analyse findings and recognise trends in the research. The absence of a standardized definition of a cataract is mainly due to the difficulty of researchers agreeing on a definition based on morphology alone (Leske and Sperduto, 1983). Therefore, a definition of a cataract should include opacification of the crystalline lens with reduction in visual acuity (Leske and Sperduto, 1983).

The Royal College of Ophthalmologists (2010), cataract guidelines state that patients with cataract should have sufficient cataract to account for their visual symptoms and that the cataract should affect the patient's lifestyle when considering referral for cataract surgery. (The Royal College of Ophthalmologists, 2010).

3.3. Prevalence

According to the World Health Organization (WHO, 2014), cataract accounts for 48% of the world blindness, affecting almost 18 million people, due to the lack of appropriate surgical facilities in developing countries. By the year 2020, it is estimated that there will be almost 54 million people aged 60 years or older that will be blind as a direct result of cataract. With an increasingly elderly population, healthcare services in many countries will see a higher incidence and/or an increased risk of cataract due to the ageing processes (WHO, 2014).

Cataracts are the most common reversible cause of visual impairment in the elderly living in developed countries, after refractive error (Dhital, Pey and Stanford, 2010). The population-based prevalence studies for cataract are difficult to compare, as different studies have used different definitions, detection and grading techniques (Said et al., 1970, Kahn, 1977, Chatterjee, Milton and Thyle, 1982,).

The most accurate recording of the prevalence of lens opacities, is the use of photographs to document the amount of cataract (Dragomirescu et al., 1978, Brown, 1979,). Examples of three population-based photo-documentation studies include the Beaver Dam Eye Study (BDES) from the United States (Klein, Klein and Linton, 1992), the Blue Mountains Eye Study (BMES) from Australia (Mitchell et al., 1997) and the Melton Eye Study (MES) from the United Kingdom (Deane et al., 1997). The photographs were assessed using the Wisconsin Cataract Grading System in BDES and in the BMES study. The advantage of using the same grading system is that the results were easily comparable between the two studies. The prevalence rates found in these two studies were very similar (see Table 3a). On the other hand, MES study used the Oxford Clinical Cataract Classification and Grading System. The prevalence data recorded from these studies are shown in Table 3(a). It is evident from these studies that cataract progressively increases with age.

Table 3a: Prevalence of cataract in recent published studies. **KEY:** Posterior Subcapsular Cataract (PSC)

Study	**Location**	**Year**	**Sample**	**Age (years)**	**Prevalence for age (%)**		
					Nuclear	**Cortical**	**PSC**
BDES	USA	1988-1990	4926	55-64	7	11	4
				65-74	27	25	8
				75-84	57	42	14
BMES	Australia	1992-1994	3654	55-64	4	13	4
				65-74	22	28	7
				75-84	49	47	12
MES	England	1992-1995	1201	55-74	*	36	11

3.4. Classification of cataracts

This study focuses solely on age-related cataracts. Other types of cataracts such as congenital, traumatic and metabolic are beyond the scope of this study. There are three main types of age-related cataracts defined by their clinical appearance; nuclear, cortical and posterior subcapsular.

3.4.1. Nuclear Cataract

With ageing, the molecules between the cells in the nucleus increase. These large molecules absorb light causing a decrease in the transparency of the lens and an increase in light scatter (Harding and Crabbe., 1984). This process, known as nuclear sclerosis, is a normal occurrence that progresses slowly over many years causing the lens to harden and become yellow (see Figure 3a). Nuclear cataracts can cause a myopic shift in refraction (Brown and Hill., 1987), due to an increase in refractive index in some lenses. Therefore many patients with this type of cataract may report an improvement in their near vision, before noticing that their distance vision has deteriorated (Malhotra, 2008). This is often referred to as 'second sight of the elderly'.

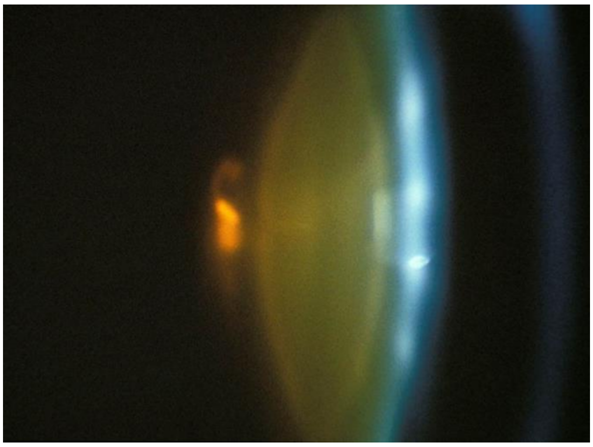

Figure 3a: Nuclear Cataract (Pesudovs and Elliott, 2001).

3.4.2. Cortical Cataract

Cortical cataracts are wedge shaped opacities found in the anterior and/or posterior lens cortex (Pesudovs and Elliott, 2001). The base of the wedge is normally hidden behind the iris in the lens periphery (see Figure 3b). Cortical cataracts occur due to water imbibitions into the lens, causing disruption to the lens fibres (Pesudovs and Elliott, 2001). The disrupted and swollen lens fibres dissolve and the precipitation of components causes the formation of opaque suspension with the lens (Pesudovs and Elliott, 2001). These structural changes within the lens causes light to scatter with huge variations in refractive index (Pesudovs and Elliott, 2001). Opacification occurs due to the scattering of light when it meets irregular interfaces between regions of different refractive index (Pesudovs and Elliott, 2001). In cortical cataracts, vision is only affected if the cortical spokes enter the pupillary area. Cortical cataracts can cause astigmatic changes and monocular diplopia (Pesudovs and Elliott, 2001).

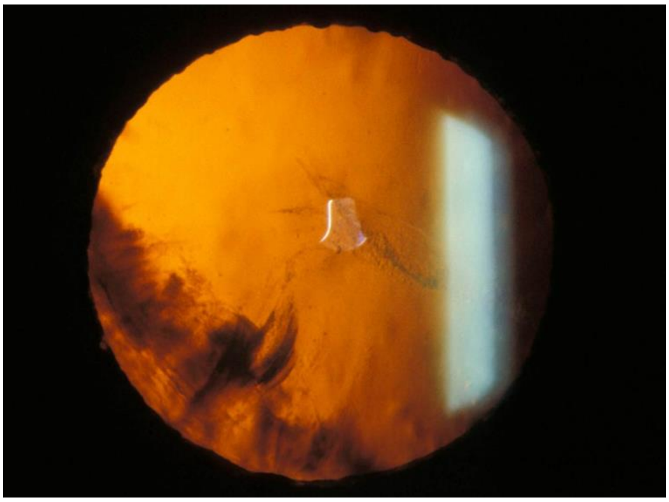

Figure 3b: Cortical cataract (Pesudovs and Elliott, 2001).

3.4.3. Posterior Subcapsular Cataract (PSC)

In posterior subcapsular cataract (PSC), granular opacities develop in the central posterior cortex of the lens (see Figure 3c). Patients with PSC complain of symptoms of disability glare and have difficultly in focusing on close up objects. This is due to the pupil constricting during close up work, causing the light entering the eye to become concentrated centrally, where the PSC is also located, causing light to scatter and interfere with the ability of the eye to focus an image onto the retina (Malhotra, 2008).

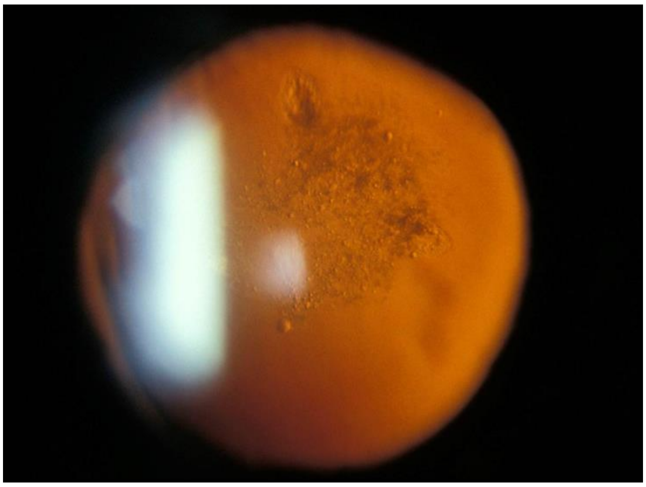

Figure 3c: Posterior Subcapsular Cataract (Pesudovs and Elliott, 2001).

3.5. Risk factors for cataract development

3.5.1. Personal Factors

(i) Age

Age is a well known risk factor for all types of cataracts. With ageing, the lens loses its clarity and, at present, this clouding cannot be prevented or reversed. The clear association of age with cataracts has been well documented by the Framingham Eye study in 1977 (Kahn et al., 1977(a), Kahn et al., 1977(b)) and in Table 3(a) presented above.

(ii) Female Sex

Numerous studies have suggested a greater risk of cortical cataract amongst women (Sperduto and Seigel, 1980, Hiller, Sperduto and Ederer, 1986). A case-control study, that controlled for numerous well-known risk factors for cataracts also found women to be at an increased risk for cortical opacities compared to the men (Leske, Chylack and Wu, 1991).

(iii) Genetic factors

Studies of families and twins have shown genetic factors to account for 50% to 70% of cataract cases and are important in the development of age-related nuclear and cortical opacities (Hammond et al., 2000, Hammond, Duncan and Snieder, 2001).

3.5.2. External Factors

(i) Smoking

West and Valmadrid (1995) reviewed studies that examined smoking as a risk factor for nuclear cataract. Of the ten reviewed, eight showed a consistent association between smoking and nuclear cataract. A population-attributable risk of smoking for nuclear cataract can reach 17% (McCarty, Nanjan and Taylor, 2000).

(ii) Sun light exposure

A review by McCarty and Taylor (2002) showed a direct association with lifetime exposure to ultraviolet radiation with prevalence of cortical cataract. Sunlight exposure presents a population-attributable risk of 10% for cortical cataract (McCarty and Taylor, 2000).

(iii) Diabetes Mellitus

Clinical studies have confirmed a higher prevalence of cortical and posterior subcapsular opacities in patients with Diabetes (Hodge, Whitcher and Satariano, 1995, West and Valmadrid, 1995). Ederer and colleagues (1981), suggest that around 4% of all cataracts are attributed to diabetes.

(iv) Corticosteroids

A review conducted by Hodge and colleagues (1995), showed a significant risk factor in the formation of posterior subcapsular cataracts with the use of both systematic and topical steroids. Inhaled steroids have also shown to increase the risk of cataracts (Cumming, Mitchell and Leeder, 1997, Jick, Vasilakis-Scaramozza and Maier, 2001).

(v) Alcohol

A number of studies have shown alcohol to be a risk factor for different types of cataract especially posterior subcapsular cataract (Munoz et al., 1993, Ritter et al., 1993). However, a large number of studies did not show this association, this may be attributable to participants providing incorrect information, considering it as embarrassing. Participants taking part in health research may well drink less. Two Australian population based studies found no increased risk of alcohol intake with the development of cataracts (Cumming and Mitchell, 1997, McCarty et al., 1999).

3.6. Referral for cataract surgery

Guidelines for cataract surgery referral from the Royal College of Ophthalmologists suggest that patients should be referred for cataract surgery if there is sufficient cataract to account for the visual symptoms and that these limit their quality of life and ability to work, irrespective of Snellen visual acuity (Royal College of Ophthalmologists, 2010).

If a patient holds a driving licence then the visual acuity must fall within the requirements for driving. The requirement for driving within the United Kingdom is the ability to read (with glasses or contact lenses, if necessary) a car number plate at 67 feet (~20m), which equates to a visual acuity of at least 6/12 (0.30 logMAR) measured on a Snellen scale (with glasses or contact lenses, if necessary) using both eyes together or if sight in one eye is present only, then the visual acuity in that eye (DVLA, 2014).

3.6.1. Pre-operative hospital assessments

The main aim of the pre-operative hospital assessment is to confirm the diagnosis of cataract and ensure the cataract is the cause of the decline in vision and not other causes such as diabetic retinopathy, macular degeneration, or glaucoma. The patient undergoes the following medical assessment of the eye and general health;

(a) Previous eye history

The presence of co-morbid eye disease (including amblyopia) needs to be determined prior to cataract surgery. If a cataract surgery is scheduled to take place on an amblyopic eye, patients need to be aware that cataract surgery in that eye may only offer limited improvement post surgery (Watts, 2005). Greater discussion on the risk and benefits should be given to those patients with vision in one eye only, as these patients will be more concerned about cataract surgery in this eye (Malhotra, 2008).

(b) Measurement of visual acuity

The best corrected visual acuity for distance and near is provided in the optometrists referral form in most cases. The visions are measured again, as some measurements may have been taken a while ago due to a delay between the initial referral and the hospital assessment. The initial measurements taken may no longer be accurate (Watts, 2005, Malhotra, 2008).

(c) Refraction

A copy of the patient's most up to date refraction along with any previous refraction is usually provided in the optometrist's referral form for most patients. If this is not available, an accurate pre-operative refraction is crucial to ensure that the correct intraocular lens implant is chosen during cataract surgery (Malhotra, 2008).

(d) Full slit lamp examination

Examination of the external eye including lids and lashes should be assessed to rule out any ocular eye diseases that could interfere with a successful cataract surgery, for example blepharitis, conjunctivitis or dry eyes (Watts, 2005). Particular attention should be paid when examining the corneal endothelium as any pre-existing corneal pathology (e.g. Fuch's dystrophy) (Malhotra, 2008) would increase the risk of complications from cataract surgery. Any weakness in the zonules supporting the lens (e.g. Pseudoexfoliation) would also increase the risk of complication from cataract surgery (Malhotra, 2008).

(e) Ultrasound and pupil examination

A clear view of the back of the eye (the fundus) may not be possible if the lens is so opaque preventing the ability to assess retinal and optic nerve function prior to cataract surgery. In this case an ultrasound test may be performed to determine the structure within the eye identifying for example a retinal detachment if present. The response of the pupil to light and the presence of relative afferent pupillary defect (RAPD) should be determined. Cataracts do not cause RAPD (Malhotra, 2008).

(f) Measurement of intraocular pressure

Uncontrolled intraocular pressure, due to glaucoma, would result in a poor visual outcome post surgery. Therefore, the intraocular pressures are measure prior to cataract surgery (Watts, 2005).

(g) Dilated eye examination

The ophthalmologist will assess the back of the eye to identify any conditions that may reduce the success of the cataract surgery. The most common being age-related macular degeneration (ARMD). Patients with ARMD may suffer with further reduction in their visual acuity due the presence of a cataract (Malhotra, 2008). The majority of patients with ARMD experience a significant improvement in their quality of life as well as visual function following cataract surgery. The increase in the severity of cataract, irrespective of ARMD, will result in further reduction in vision. As discussed above, cataract causes reduced distance and near vision acuity as well as contrast sensitivity. Due to this, patients would benefit from cataract surgery despite the presence of ARMD. However, some studies have suggested that patients with ARMD that undergo cataract surgery are at a slightly higher risk of developing wet ARMD (Glaser and Lester, 2002). With this in mind, patients with ARMD should be cautious of the possible complications post cataract surgery. It is also well known that diabetic patients with cataracts are at a greater risk of post-operative complications including posterior capsule opacification (PCO), anterior segment neovascularisation increased progression of diabetic retinopathy and macula oedema (Steel et al., 2008). Due to these complications the post-operative visual acuity may therefore be poor. If a patient has proliferative diabetic retinopathy (PDR) and/or macula oedema these should be treated prior to cataract surgery and the patient should be counselled on the guarded prognosis to their vision after cataract surgery.

Following the above assessments the ophthalmologist will now be able to advise on the likely gain in vision following cataract surgery and if, for any reason, this may be affected due to other diseases that may have been detected. The ophthalmologists will summarise the risk and benefits of the surgery to the patient. If the patient is happy to proceed with the surgery, consent is obtained and the measurements of the eye to be operated on are taken, see below.

3.6.2 Biometry of the eye

The term biometry is used to describe the measurements taken of the eyes for the purpose of selecting the power of the lens to be implanted during the surgery (Watts, 2005). The two key measurements needed to accurately determine the lens implant power are;

1) The length of the eye ball.
2) Curvature of the cornea.

These measurements are then entered into a complex mathematical formula which predicts the lens power needed (Malhotra, 2008).

A keratometer is used to measure the curvature of the anterior surface of the cornea. This procedure is painless as it does not involve contact with the eye. This technique is extremely accurate however misleading results can occur if the cornea is scarred or if a patient has had previous refractive laser surgery (Watts, 2005).

The length of the eye is measured from the front of the cornea to the retina using ultrasound. Before this measurement is taken, anaesthetic drops are placed in the eye so that the procedure is painless. A small probe is then placed on to the front surface of the cornea and ultrasound waves are emitted. The time taken for the wave to reach in to the eye and reflected back to the probe by the retina is measured. The speed the wave has travelled within the eye is known. The distance from the front of the cornea to the retina can then be calculated (Watts, 2005).

Optical interferometers (IOLMaster: CarlZeiss) designed for lens implant power calculations are now widely available and used. They can measure the length of the eye, curvature of the cornea and the anterior chamber depth of the eye. The in-built formula calculates the lens implant power. The advantage of this system is that it does not require direct contact with the eye and is ideal for patient comfort with good compliance. The disadvantage of this system is that dense cataracts and corneal opacities may preclude measurements with this system (Malhotra, 2008).

In most cases the intraocular lens (IOL) power chosen will leave the patient emmetropic, (no refractive power needed) allowing clear distance vision but needing near vision spectacles for reading. However, there are a number of factors that need to be taken into account when selecting the strength of the IOL to be implanted. If cataract surgery is planned in one eye only it is important not to leave the patient with an intolerable degree of anisometropia (unequal refraction in the two eyes). For example, if a patient is highly myopic (highly short-sighted) and is only having one eye operated on, if the operated eye is left emmetropic after surgery, as is normally done in most cases, this patient will be at a high risk of post-operative anisometropia. In most cases, this patient is usually left with low myopia (slightly short-sighted) in the operated eye. However, if this patient was having both eyes corrected, emmetropia is a possible option provided the second eye is operated on soon after the first eye. The ophthalmologist would discuss all these options with the patient prior to surgery (Malhotra, 2008).

Biometry is a critical step in preparation for cataract surgery. Insertion of a wrong power of lens implant will not result in the intended visual outcome. The lens power selection should be carefully discussed with the patient so they are fully aware of the intended post surgery vision and refraction outcome.

3.6.3. Cataract surgery

Currently, cataract development cannot be reversed or delayed. The main treatment option for cataract is surgery; however in the early stages of cataract development many patients benefit from updating their glasses to improve their vision, as cataracts can cause refractive changes. Once the cataract is at a stage where the vision cannot be improved via glasses and the patient reports the cataract is now affecting their daily lifestyle, their optometrist may, at this point, recommend cataract surgery. Cataract surgery is highly successful (Javitt et al., 1993), however as with any surgery there are risks involved. The operating consultant would discuss the risk and benefits after the initial hospital pre-assessment outcome (see above) as all patients' cases are different involving different risks and benefits.

Over 90% of cataract surgeries in the UK are performed under local anaesthesia as a daycase procedure (Malhotra, 2008). A small incision between 1.8mm to 3.2mm is made at the junction between the end of the cornea and the sclera just under the upper lid (Watts, 2005). The incision is made to allow the lens to be replaced with another new lens, the Intra-Ocular Lens (IOL). The incision is small so is self-healing with no stitching required. The aim of the surgery is to remove the lens from its bag whilst leaving the bag intact to support the new lens. A circular tear 6mm in diameter is made at the front of the bag leaving a good size rim at the front of the bag to support the new lens (Watts, 2005). Phacoemulsification cataract extraction is now the modern technique used to remove the lens. The word 'phaco' derives from the Greek meaning lens and 'emulsification' meaning turning into an emulsion. Therefore, phacoemulsification is the process of turning the lens into fluid so it can then be sucked out of the eye (Watts, 2005). This is done by breaking up the lens into small fragments using an ultrasound probe that converts electrical energy into vibrating shockwave energy. It is the vibration of the probe that liquefies the hard lens (Malhotra, 2008). Once all the lens fragments have been sucked up the new lens can then be inserted. The modern IOLs are made from a variety of materials, with silicone or acrylic polymers being the most common. Surgeons are now using foldable IOLs as they can be inserted into the eye without enlarging the wound, so that sutures are not required and reduce the risk of distortion or induced astigmatism (Watts, 2005).

3.6.4 Outcomes and complications of surgery

Cataract surgery is seen as a safe and successful procedure. However, complications can occur at any stage and the visual outcome may not always reach the patients expectations.

Most studies reporting the outcome of cataract surgery measure high contrast acuity only. This measure is important in the assessment for the eligibility to drive, join uniformed services and in obtaining vision impairment certificates. Many studies have now started to report the results of the surgery from the point of view of the patients' experience using a variety of patient reported outcomes (Black et al., 2009., Lundstrom and Pesudovs, 2009). These studies have confirmed that cataract surgery is beneficial to the overall outcome especially if surgery to the second eye is performed (Laidlaw et al., 1998, Lundstrom, Stenevi and Thorburn, 2001).

During phacoemulsification the tearing of the posterior lens capsule is the most common complication that can occur with an incidence ranging from 0.7% to 16% (Vajpayee et al., 2001). The visual outcome for patients with a capsule tear is not as good as uncomplicated surgery (Chan et al., 2003, Ang and Whyte et al., 2006).

Other complications that can occur with cataract surgery are cystoid macula oedema with an overall incidence of around 1-2% (Schmier et al., 2007). This rate is increased in patients with pre-existing conditions. The incidence of retinal detachment after phacoemulsification ranges from 0% to 3.6% (Lois and Wong, 2003, Russell et al., 2006).

In this study after the surgery was conducted, the patients' GPs were notified of the outcome of the surgery via a letter from the surgeon and a copy was filed in the patients' medical records. Only patients that had successful cataract surgeries with no complications were included in this study, as a poor outcome may affect the falls rate in these patients and it may be due to the complication of the surgery causing the fall.

3.7. Age-related macular degeneration (ARMD)

The macula is a small central area of the retina responsible for detecting fine detail. The blood vessels under the retina supply the macula with nutrition. With ageing, waste products build up under the retina, forming small yellow moulds of debris known as drusen. Over time, the debris accumulates moving the retina further away from the blood supply preventing the transfer of nutrition to the retina. The term macular degeneration is used to describe the abnormality of the blood supply to the macula (Glaser and Picker, 2002).

Age-related macular degeneration (ARMD) is the leading cause of irreversible visual impairment in the UK (NHS choices, 2013). ARMD most commonly affects people aged over 50 (NHS choices, 2013). Approximately 30% of people over the age of 75 have early signs of ARMD and around 7% have a more severe form of ARMD (NHS choices, 2013).

Macular degeneration is classified into two types, dry and wet. In dry macular degeneration, the blood supply to the macular is reduced, causing the retinal cells to gradually waste away, leading to gradual vision loss. The dry form of the macular degeneration affects 90% of patients (Glaser and Picker, 2002). In wet macular degeneration, new blood vessels form to improve the blood flow to the retina. However, these new blood vessels may over time leak blood or fluids under the retina in the macular region resulting in rapid severe vision loss. The wet form of macular degeneration affects around 10% of patients (Glaser and Picker, 2002).

Dry macular degeneration causes blurring in the central field of vision which progresses over a period of months or years. Wet macular degeneration causes distortion in the central field of vision which progresses rapidly over days or weeks (Glaser and Picker, 2002).

The most important risk factor for ARMD is age. Studies have confirmed the increased risk of ARMD with increasing age (Klein, Klein and Linton, 1992, Mitchell et al., 1995). There is strong evidence showing that people who smoke are at a much higher risk of getting ARMD than people who do not smoke (Smith, Mitchell and Leeder, 1996, Vingerling, Hofman and Grobbee, 1996). Poor dietary intake may also influence the risk of developing ARMD by causing an increase in fat deposits under the retina affecting the blood supply to the macula (Mares-Perlman et al., 1995).

Currently there is no treatment available for dry macular degeneration, however to delay the progression of dry macular degeneration it as advisable to stop smoking, maintain a healthy diet, control high cholesterol and protect the eyes from sunlight. The current treatment for wet macular degeneration involves reducing the leakage of the new blood vessels under the retina (Glaser and Picker, 2002).

3.8. Glaucoma

Glaucoma is a chronic neurodegenerative disease of the optic nerve (Healey and Thomas, 2010). Glaucoma can be classified into primary or secondary glaucoma. In primary glaucoma, the mechanism of the disease is unknown. In secondary glaucoma, an ocular or systemic disease causes secondary glaucoma damage (Healey and Thomas, 2010). Primary and secondary glaucomas can be further classified into open angle and angle closure, referring to the anterior chamber angle being open or narrow. Primary Open Angle Glaucoma (POAG) is the common type with usually no noticeable symptoms, as the glaucoma progresses the patients notices their outer field of vision (Peripheral vision) is affected and slowly working inwards towards the centre of their vision. Primary Angle Closure Glaucoma (PACG), develops rapidly with severe symptoms including; painful red eye, headache and loss of vision in one or both eyes that progresses very quickly. In secondary glaucoma symptoms vary depending on the cause. Secondary glaucoma can be caused by eye injuries, medications and operations (Healey and Thomas, 2010).

In the UK around 10% of cases of blindness are due to glaucoma (Bunce and Wormald, 2006). Early detection of glaucoma is imperative to prevent irreversible visual loss (Fraser et al., 2001).

Numerous risk factors for the onset and progression of glaucoma have been identified. The most important risk factor is increased intraocular pressure (IOP) (Leske et al., 1995). High systemic blood pressure is another risk factor that has been documented in several studies (Morgan and Drance, 1975, Leske and Podgor, 1983,) to cause an increase in IOP.

The main aim of the treatment of glaucoma is to maintain the IOP at a level at which the progression of the disease is at an acceptable low rate (Healey and Thomas, 2010). Patients diagnosed with glaucoma require life-long monitoring, with regular optic nerve, IOP and visual field checks.

3.9. Diabetic Retinopathy

In 2010, there were approximately 3.1 million people aged 16 or over with diabetes in the UK. It is estimated that this figure will increase to 4.6 million by the year 2030 (NHS Choices, 2013). In the UK, 90% of the patients with diabetes are type 2 diabetics (NHS Choices, 2013).

Diabetic retinopathy (DR) is a disease of the retinal microvasculature associated with excess sugar level and with other conditions associated with diabetes such as hypertension (Steele et al., 2008). DR is potentially a blinding disease if there is damage to the macula (Diabetic maculopathy (DM)) or the development of new vessels leading to retinal detachments (Steele et al., 2008). In 2002, diabetic retinopathy was the most frequently reported cause of serious visual loss in people among the working age group in Europe (Kocur and Resnikoff, 2002).

Patients with diabetic retinopathy can be treated with laser photocoagulation and vitrectomy surgery. Diabetes is an important risk factor for cataracts. Diabetic patients with no diabetic retinopathy or with mild retinopathy that have not undergone laser treatment can expect similar visual outcomes to those patients with no diabetes (Fong et al., 2010).

3.10. Summary

Cataracts account for almost 48% of world blindness. Patients undergoing cataract surgery have a high expectation of the overall post visual outcome, therefore it is the role of the Ophthalmologists to discuss all the risk and benefits of the surgery and select appropriate lens power for each individual patient based on their individual circumstances. In this chapter, age-related eye diseases were briefly discussed as they are relevant by virtue of the fact that some of the study's participants presented with these in addition to their cataract. Participants were only included in the study if the ophthalmologist deemed cataract surgery would benefit the overall visual outcome of the patient despite any other age-related eye diseases they may have.

CHAPTER 4

LITERATURE REVIEW: VISUAL IMPAIRMENT AND FALLS IN OLDER PEOPLE

This chapter will review the literature regarding the prevalence of visual impairment and its implications as a risk factor for falling. Before reviewing the literature, it is important to note that the definition of visual impairment has not been standardised. Consequently, this makes it difficult to compare and generalise the findings, from all of the various research studies that have been conducted.

4.1. Definition of visual impairment

The World Health Organisation (WHO) International classification of visual impairment is 'binocular best-corrected visual acuity worse than 6/18 (~ 0.48 logMAR) but equal to, or better than 6/120 (1.30 logMAR)' (Foran et al., 2002). In contrast the American definition classifies visual impairment with reference to monocular vision; as 'worse than 6/12 (0.30 logMAR) but better than 6/60 in the better eye' (Foran et al., 2002). Consequently, the disparities between the definitions of visual impairment make it difficult to compare and draw conclusions upon the findings from existing studies.

4.2. Prevalence of Visual Impairment

Based on the WHO criteria, in 2000, it was estimated that within the UK 14.3% of people aged 65 years and over, were visually impaired (van der Pols et al., 1999).

When age was sub-categorised, the figures for the prevalence of visual impairment were 3% in the 65-74 age group, 12% in those aged 75-84 and 36% in those aged over 85 years.

However, there are discrepancies in the reported prevalence of visual impairment between studies. This is partly due to differences in definitions of visual impairment used. Additionally, it is also due to the varied visual acuity charts and testing protocols used in different countries, e.g. developed and developing countries. It is therefore difficult to know precisely how prevalent visual impairment actually is.

4.3. Visual Impairment and falls

4.3.1. Under-corrected refractive error

The leading cause of visual impairment in developed countries is under-corrected refractive error (Black and Wood, 2005). Evans and Rowlands (2004) reviewed the relevant literature and suggested that between 7%-34% of older people living in developed countries had visual impairment rectifiable simply by updating their spectacles.

A study conducted by Jack et al (1995) investigated 200 patients aged 65 years and over, who were admitted to the Royal Liverpool University Hospital with an acute medical illness. A Snellen chart was used to measure distance visual acuity with the distance spectacles that were usually worn; 51% of the patients were found to have impaired vision (binocular acuity 6/18 or worse). This figure increased to 66% for those over the age of 85 years. Of the 101 patients with impaired vision, 79% had a visual impairment that was correctable, either by the correction of refractive error or by the surgical removal of cataract. In the group with refractive errors, approximately 60% had not visited an optometrist in the past 3 years. Although a dated study, this suggests that within the UK there may be many older people with outdated spectacles or no spectacles at all who may benefit from an updated prescription.

Another study based in the United States reported that 47% of 2433 older adults aged 55 to 99 years with a median age of 70.7 years had not had their eyes tested in the past year (Puent et al., 2005). The American Optometric Association (AOA) recommends annual examinations for adults aged 60 and over (AOA, 2014). This study also found that 37% of those who wore corrective spectacles could benefit from a visual intervention (Puent et al., 2005). Such high figures indicate that older people may not be aware of their declining vision and the need for regular eye examinations and updated spectacles.

Currently, there are no clear explanations as to why so many people have correctable but untreated visual impairment. It may be that older patients assume that poor vision is an inevitable consequence of ageing and therefore there is no need to use the optometric services (Evans et al., 2002). Furthermore, reduced access to eye care may also be an important barrier for some frail, older people (Menant, Smith and Lord, 2008). Moreover, many older patients fear the expense of new spectacles and therefore avoid optometric services (Shickle and Griffin, 2014). This is despite free eye tests for the over 60's in the UK.

As a result many elderly people do not receive the appropriate treatment for their reduced visual function, which may contribute to the high prevalence of falls in this population. Falls research estimates that reduced visual acuity approximately doubles the risk of a fall (Ivers et al., 1998, Klein et al., 2003). As a result, the use of appropriate refractive correction for older individuals should significantly reduce the incidence of falls (Black and Wood, 2005), although this has not been confirmed in randomised controlled trials.

4.3.2. Cataracts

Cataracts are the most common reversible cause of visual impairment in the elderly, after refractive error (Dhital, Pey and Stanford, 2010). According to the World Health Organization (WHO, 2014), cataract accounts for 48% of the world blindness, affecting almost 18 million people. The benefits of cataract surgery in reducing the risk of falls will be discussed in the next chapter.

4.3.3. Age-related macular degeneration (ARMD)

Age-related macular degeneration (ARMD) is the leading cause of irreversible visual impairment in the UK (NHS choices, 2013). A cross-sectional study conducted by Szabo and colleagues (2008) investigated 115 community-dwelling women aged 70 years and over with wet AMD (AMD cohort) and two control groups: 54 community-dwelling women without wet AMD from the same community (non-AMD cohort) and 341 community-dwelling Australian women (Australian normative cohort). Older women with ARMD were shown to have impaired balance, slower visual reaction times and poorer vision than their age-matched controls (Szabo et al., 2008). These factors combined may lead to a greater risk of falls. The mean fall risk score of 3.20 in the ARMD cohort group was significantly greater than that of the non-ARMD cohort with a score of 1.21 (Szabo et al., 2008). Furthermore, Wood and colleagues (2009) assessed postural stability and gait in patients with ARMD to try to identify the visual factors that may be associated with these deficits. After adjustments for age, sex, self-reported physical function and cataract severity, all the visual factors, particularly contrast sensitivity, were associated with postural instability and changes in gait. These results suggest that the loss of contrast sensitivity in patients with ARMD can lead to balance and mobility problems (Wood et al., 2009). It is therefore important that in order to reduce the risk, these patients are provided with appropriate advice on fall prevention strategies.

4.3.4. Glaucoma

In the UK around 10% of cases of blindness are due to glaucoma (Bunce and Wormald, 2006). Early detection of glaucoma is imperative to prevent irreversible visual loss (Fraser et al., 2001). The association between visual fields loss due to glaucoma and an increased risk of falls will be discussed in section 4.

4.3.5. Diabetic Retinopathy

Diabetic retinopathy can result in visual impairment in older people. In 2002, diabetic retinopathy was the most frequently reported cause of serious visual loss in people among the working age group in Europe (Kocur and Resnikoff, 2002). Currently, there is little literature associating diabetic retinopathy to falls. Nevertheless, the systemic manifestation of diabetes and the effects of lower limb neuropathy may affect walking, gait and increase the risk of falls (Paul et al., 2009).

4.4. Specific aspects of visual functions and falls

Many studies have investigated the relationship between specific visual functions and falling in older people. The overall evidence indicates that older people with visual impairment are twice as likely to fall, as normal sighted elderly individuals (Ivers et al., 1998, Klein et al., 1998, Coleman et al., 2004, de Boer at al., 2004). However, there are still some inconsistencies within the literature regarding which aspect of vision is implicated.

4.4.1. High-contrast distance visual acuity

The most commonly investigated visual function in relation to falls is high-contrast distance visual acuity. Numerous large cross-sectional population studies have consistently reported a significant association between reduced visual acuity and falls.

The Beaver Dam Eye Study collected retrospective falls data from 3722 subjects who participated in a 5-year follow-up of the Beaver Dam Eye Study cohort. Distance visual acuity was measured using the logMAR ETDRS chart binocularly with their current spectacles (if they wore them for distance). They found 2.6 times higher risk of multiple falls in those participants aged 60 years or older, if habitual binocular visual acuity was 6/7.5 or worse (Klein et al., 1998). The Blue Mountains Eye Study collected retrospective falls data from two postcode areas in Blue Mountains west of Sydney, Australia (Ivers et al., 1998). People aged 43 years and over were invited to participate in the study. Of the 4433 eligible residents, 3654 took part in the study and 3299 answered questions about falls. Participants were given a detailed eye examination and answered questions about health and vision status, use of medication and the number of falls in the previous 12 months. The study showed that multiple falls were approximately twice as likely to occur after adjustments for confounders, when habitual binocular visual acuity was worse than 6/9. Both these studies are limited by their retrospective nature. However, the use of such large sample sizes provides convincing statistical evidence of the link between reduced visual acuity and falls.

In addition, falls have been linked with a *change* in visual acuity, as well as a poor level of visual acuity. A large scale prospective study by Coleman and colleagues (2004) found that women aged over 65 years (n=2002), whose visual acuity had decreased by two or more lines on a Bailey-Lovie chart in the previous four to six years, were 43% more likely to have multiple falls in the following year than women whose visual acuity had reduced by less than two lines over the same period.

In contrast prospective studies (see section 2.2) have failed to show any significant link between visual acuity and falls using univariate analysis (Campbell, Borrie and Spears, 1989, Lord et al., 1991, Friedman et al., 2002, Stalenhoef et al., 2002,). These studies however have used smaller sample sizes, which can reduce the level of significance of the risk factors.

A large prospective cohort study conducted by Tromp and colleagues (2001), followed 1285 community-dwelling adults aged 65 years and over for one year. Falls during that year were ascertained using fall calendars. Participants were instructed to complete the calendars on a weekly basis. In this study, distance vision was ascertained by questioning the participants on whether they could recognize someone’s face at a distance of 4 metres, with glasses or contact lenses if needed. A standardised visual acuity test chart was not used in this study, therefore making it harder to compare results with other studies. This self-reported vision question was ascertained at the beginning of the study. Falls were then ascertained for a year, during that year it is very likely for their vision to have changed from the baseline measurement, especially in this age group of participants where age-related eye disease are becoming more apparent. Since vision was not measured at the time of the fall, the vision data may not be entirely accurate. Overall, this study found that reduced self-reported visual acuity was linked with an increased risk of any falls with an odds ratio of 1.6 (95% CI 1.2-2.1) and recurrent falls with and odds ratio of 2.3 (95% CI 1.5-3.4) obtained by the multiple logistic regression (Tromp et al., 2001). This study did not adjust for age, gender or other variables as the study wanted to identify subgroups with highest risk and not on the identification of casual risk factors (Tromp et al., 2001).

A large study conducted in Melbourne, Australia by Morris and colleagues (2004) retrospectively collected falls data using a questionnaire. 1000 participants (533 women) aged 65 years and over (median 72 years) took part in the study. The questionnaire asked the participants to report how many falls, if any they had in the last 12 months and whether any falls required medical attention (see section 2.2 on retrospective falls reporting). They used a 4-point self-reporting vision scale that ranged from excellent to poor. This was then further dichotomized into excellent or good versus fair and poor. The vision in this study was also measured after the fall event, so accurate vision data at the time of the fall may have been different to that reported in the study. This study also reported poor self-rated visual acuity was linked with multiple falls with and odds ratio of 2.61 (95% CI 1.67-4.07). This study used the multivariate analysis taking into consideration age and gender (Morris et al., 2004).

In contrast to the above studies, Graafmans and colleagues (1996), followed 458 (men and women) aged 70 years or older for a period of 28 weeks. Participants were asked to record, on a weekly basis in a diary, whether or not they had fallen, as well as the location, time and circumstance of each fall. Very little information is given in this study as to the exact measurement of vision, however it stated that a questionnaire was used to ascertain poor distance vision with glasses, if worn. The study found no link between poor self-reported distance vision and falls.

A very similar study to the Tromp and colleagues study above was conducted by de Boer and colleagues (2004). They too conducted a prospective cohort study, by following 1509 older men and women (55-85 years of age) for 3 years. Participants in this study were also asked to record fall events every week on a falls calendar. Vision was ascertained by questioning the participants on whether they could read the small print in the newspaper, or like in the Tromp et al study above, if they could recognise someone's face at a distance of 4 metres, with glasses or contact lenses. Both of these questions in this study were scored on a four-point scale. These scores were then dichotomized into no difficulty or little difficulty versus much difficulty or cannot see. This study found no link between self-reported visual distance or near vision and falls.

These studies that have used self-reported measures of vision have reported conflicting results. These differences are likely to be due to the variable nature of such subjective and non-standardised self-reported measures of vision. No assessments were made regarding the validity or repeatability of these self-reported assessments in any of the studies.

4.4.2. Contrast Sensitivity

Black and Wood (2005) concluded from their review that adequate visual information across all spatial frequencies is required to avoid trip hazards and to negotiate stairs. The measure of contrast sensitivity is more highly correlated with performance in mobility tasks than visual acuity (Marron and Bailey, 1982). Similar to other aspects of vision assessment in falls studies, comparison of contrast sensitivity studies and falls is problematic, because different tests have been used to measure contrast sensitivity at a variety of spatial frequencies.

Anand and colleagues (2003a), suggested that postural stability depended more on lower spatial frequency information than high spatial frequencies. Contrast sensitivity was measured using the Pelli-Robson chart at a distance of 1m. Similarly, Lord and Menz (2000) revealed that contrast sensitivity measured using the Vectorvision CSV-1000 chart was an independent predictor of postural stability but visual acuity was not. Therefore, a reduction in contrast sensitivity at the low and mid spatial frequencies may be an important risk factor for falls due to their roles in postural stability.

The Blue Mountain Eye study, found that a reduction in contrast sensitivity at a range of spatial frequencies was significantly associated with two or more falls, after adjusting for confounders (Ivers et al., 1998). Contrast sensitivity in this study was measured using the Vectorvision CSV-1000 chart. Similarly, Klein and colleagues (2003) found that a reduced Pelli-Robson contrast sensitivity increased the risk of falls by a factor of 1.63. The distance from which the contrast sensitivity measurements were taken is unknown. Prospective studies have also confirmed that reduced contrast sensitivity can increase the risk of falls. Moreover a three-year study by de Boer and colleagues (2004) showed that after adjustments for potential confounders, contrast sensitivity was associated with recurrent falling (hazard ratio 1.5). Contrast sensitivity was assessed with the VCTS_6000-1 chart for near vision.

However, there have been a number of studies that have failed to find any significant association between reduced contrast sensitivity and falls. A prospective study conducted by Nevitt and colleagues (1989) followed 325 community-dwelling adults aged 60 years and over for one year to ascertain the rate of falls in that year. Participants were asked to recall any fall events on a weekly basis onto a provided postcard. Contrast sensitivity was measured at the start of the study using the Grating Test for Contrast Sensitivity. Very little information was given in this study about the contrast sensitivity test used. The test was done at the start of the study prior to the fall events entries. This could have an effect on the possible association between contrast sensitivity and falls, as the measurements were not taken at the time of the fall event. This study did not find an association between falls and reduced contrast sensitivity.

A longitudinal study conducted by Friedman and colleagues (2002), followed 2212 community-dwelling adults aged 65 to 84. Contrast sensitivity in this study was measured at baseline and at the end of the 20 month study period. The Pelli-Robson chart was used to measure contrast sensitivity under controlled room illumination at a distance of 1 metre. Falls in this study were measured retrospectively by asking the participants if they had fallen in the last 12 months (Friedman et al., 2002). This study also found no link between reduced contrast sensitivity and falls.

The available literature suggesting that impaired contrast sensitivity is linked with an increased risk of falls is ambiguous. This lack of clear association between impaired contrast sensitivity and the risk of falls may be due to the use of a variety of contrast sensitivity tests, different population sample sizes, in addition to the variation in the cut-off criteria used to define impaired and normal contrast sensitivity (Black and Wood, 2005). The data available are therefore inconclusive regarding a link between reduced contrast sensitivity and falls.

4.4.3. Depth Perception

Reduced depth perception has been found to be a significant risk factor for falls (reviewed in Menant, Smith and Lord, 2008). This may be due to inaccurate foot placement during activities such as negotiating stairs and avoiding obstacles. Depth perception has been found to be an independent predictor of postural stability in older individuals (Lord and Menz, 2000). Older individuals with poor stereoacuity were found to have a significantly higher risk of suffering recurrent falls (Nevitt et al., 1989).

One study found impaired depth perception to be the strongest risk factor for multiple fallers in 156 community-dwelling men and women aged 63 to 90 (Lord and Dayhew, 2001). Those participants with good vision in both eyes had the lowest rate of falls. Importantly participants with good vision in one eye, and only moderate or poor vision in the other eye (equivalent to those with moderate or poor vision in both eyes) had increased falling rates. This suggests that adequate depth perception appears to be an important factor for maintaining balance, and detecting and avoiding hazards in the environment.

In summary, although an association between depth perception and increased risk of falls is likely, the evidence is inconclusive due to the limited number of studies available, along with the use of different depth perception measures.

4.4.4. Visual field loss

Black and Wood (2005) found no clear evidence to support an association between visual field loss due to glaucoma and an increased risk of falls in their review. However, a more recent case-control study, involving patients with glaucoma and relatively mild field defect, were shown to be over three times more likely to have suffered from a fall in the previous year (Haymes et al., 2007). The association between visual field loss and falls is confirmed in the literature (Coleman et al., 2007, Haymes et al., 2007, Black et al., 2008).

The Salisbury Eye Evaluation study assessed the association between visual acuity, contrast sensitivity, visual field and steroacuity and risk of falling in the elderly (Freeman et al., 2007). The study found that peripheral visual field loss was the primary vision component that increased the risk of falls. Since primary open angle glaucoma is the leading cause of visual field loss in the elderly population (Ramrattan et al., 2001) it is important to prevent visual field loss by the early detection of glaucoma. Furthermore, fall prevention strategies need to be considered and employed, by people with visual field loss.

4.5. Hip fractures and visual impairment

Most hip fractures result from falls (Abdelhafiz and Austin, 2003). Prospective hip-fracture studies have provided much more consistent evidence to support an association between reduced visual acuity and fractures. This may be due to the accurate reporting of hip fractures, as hip fractures generally require medical attention and are therefore documented in the medical records by medical staff, this can be compared to self-reported falls which may not be as accurate as there is no requirement to make a contemporaneous record of the falls in the eyes of a faller (see section 2.2).

In the Framingham study (Felson et al., 1989), 2633 men and women were followed for ten years after an eye exam; 110 of whom sustained hip fractures. The fracture rates in those with moderately impaired (6/9 to 6/24) vision in the best eye subjectively and poor (6/30 or worse) vision in the best eye subjectively were higher than in those with good (6/7.5 or better) vision in the best eye subjectively. After adjustments for age, sex, weight, alcohol consumption and oestrogen use (in women); the relative risk of fracture in those with moderate impairment in vision in the best eye was 1.54, while for those with poor vision the relative risk was 2.17 (Felson et al., 1989).

Similarly, in the French EPIDOS retrospective study (n=7575), reduced visual acuity was a significant risk factor for hip fractures (Dargent-Molina et al., 1996). Women who had habitual visual acuity of 6/15 or worse were approximately twice as likely (Relative Risk=2.0 [95% CI 1.1-3.7]) to suffer a hip fracture than those with visual acuity better than 6/9.

Numerous large population studies have also confirmed the link between visual acuity and the occurrence of hip fractures. In order to determine the association between poor vision and the risk of hip fractures, the Blue Mountain Eye Study followed 3654 community-dwelling Australians aged 49 and over for a two year period. They found the adjusted hazard ratio for the risk of hip fracture in those with best-corrected visual acuity in the best eye worse than 6/18 was 8.4 (Ivers et al., 2003). The Beaver Dam Eye Study found that the odds of a hip fracture within a five-year retrospective period increased by a factor of 1.75, if best-corrected vision in the best eye was 6/12 or worse (Klein et al.,2003).

Self-reported visual impairment is a significant risk factor for hip fractures. In a case control study in Auckland (911 cases and 910 controls), hip fracture risk increased up to 1.4 times for those who self-reported their vision as adequate or minimal/blind rather than good. In addition, the risk of hip fracture increased significantly by a factor of 1.5 for those with binocular visual acuity worse than 6/18 after adjustments for age, sex, proxy response, hours of activity per week, and height, which is similar to the level of self-reported measures (Ivers et al., 2000).

Overall the evidence base supports the association between visual impairment and hip fractures and the need for visual assessments to those patients that have suffered a hip fracture to prevent further falls and fractures.

4.6. Summary

With such high prevalence of treatable visual impairment in the elderly population, it is important to identify these patients. It is evident from the literature reviewed in this chapter that visual impairment is an important risk factor for falls. However, there are still inconsistencies within the literature regarding which aspect/s of vision is implicated as the most important risk for falls.

CHAPTER FIVE

LITERATURE REVIEW: VISION INTERVENTIONS FOR PREVENTING FALLS

In chapter four, visual impairment was shown to be a significant risk factor for falls. It was evident from the reviewed literature that a significant proportion of visual impairment in the elderly population, was due to under corrected refractive error and cataracts. As a result, numerous studies have suggested that falls could be reduced by updating spectacles and performing cataract surgery. This chapter will review the available literature on the same.

5.1. Cataract surgery intervention studies

Brannan and colleagues (2003) used a prospective study design to investigate the fall rates before and after cataract surgery, without a comparison control group. Of the 84 participants who completed the study, 31 experienced a fall in the six months leading up to their cataract surgery (37%), equivalent to an annual falls rate of 74%; whilst six months after their surgery, only 8 participants recorded a fall (10%) equivalent to an annual falls rate of 20%. This suggests that cataract surgery is an effective intervention in reducing the risk of falls, in the elderly population with cataracts. However, this study has limitations, in that the participants were fully aware that they were taking part in a falls study and therefore may have been more careful after their operation, thus resulting in fewer falls after the surgery compared to the extremely high falls rate reported before the operation, much higher than expected (see section 2.3). They may have also been biased towards reporting fewer falls post-surgery (the definition of a fall is not always clear cut and can be open to interpretation by participants, see section 2.1). In addition, it is an open study with no control group.

Harwood and colleagues (2005) conducted a randomised controlled trial (RCT) of the effects of first eye cataract surgery on reducing the risk of falls using an expedited surgery group (approximately 4 weeks wait) and a waiting list control group (12 months wait). 306 women aged 70 years or older with cataracts were randomised, to the expedited (n=154) or the waiting list control group (n=152). The exclusion criteria included major refractive error, ophthalmic diseases that might reduce acuity or restrict visual fields following cataract surgery and those with cognitive impairments. Falls were ascertained by a diary, with follow up checks every three months. Participants were followed for 12 months, 76 (49%) of the operated participants fell at least once during that period and 28 (18%) fell more than once. Of the un-operated participants 69 (45%) fell at least once and 38 (25%) fell more than once. The rate of falling was reduced by 34% in the operated group, (rate ratio 0.66, 95% confidence interval 0.45 to 0.96, p = 0.03) which was primarily a reduction in the number of recurrent falls in the operated group (Harwood et al., 2005), but no reduction in overall falls rate. This figure shows a statistically significant reduction in the rate of recurrent falls amongst the operated group, but no reduction in overall falls.

A follow-on study by the same researchers aimed to determine if second eye cataract surgery would lead to a further reduction in falls (Foss et al., 2006). 239 women aged 70 and over, who had been referred to a hospital ophthalmologist department for second cataract eye surgery, were randomized to either expedited (approximately 4 weeks wait) or routine (12 months wait) surgery. The participants were followed for over 12 months and 48 (40%) operated participants fell at least once, whilst 22 (18%) fell more than once. 41 (34%) un-operated participants fell at least once and 22 (18%) fell more than once.

The rate of falling (total number of falls/number of days in the trial) was 2.9 per 1000 patient-days in the operated group and 4.3 per 1000 patient-days in the control group. The rate of falling was reduced in the operated group however, it was not statistically significant (rate ratio 0.68, 95% CI 0.39-1.19, P=0.18). Had this study incorporated a larger sample size, a 32% reduction in falls could have reached statistical significance. However, the success of their first cataract study prompted policy changes to expedite cataract surgery for all older people and this made the recruitment of control participants difficult. Desapriya and colleagues (2010) concluded that there was no evidence that cataract surgery reduced fall rates, after combining the data from the two RCT studies (i.e. Harwood et al., 2005; Foss et al., 2006) in a meta-analysis.

Another study by McGwin and colleagues (2006) compared the fall rates in patients aged 55 years and over, who had undergone cataract surgery (surgery group, n= 122) to a control group of cataract patients who did not (no surgery group, n=92). Patients were interviewed at baseline, and two years after baseline, and asked if during the previous 12 months they had fallen, had difficulty with mobility, or had difficulties with balance. Exclusion criteria included amblyopia, reduced mental capacity, use of a wheelchair, or any disease that could prevent annual visits to the optometrists. After adjusting for demographic, behavioural, medical and visual characteristics, the results showed no statistical difference between the surgery group and the control group in the likelihood of falling (risk ratio 0.96, 95% CI 0.64-1.42).

However, one methodological weakness in the McGwin and colleagues (2006) study was that participants were not randomized into the two groups, and instead they either chose or declined cataract surgery, this may open up the results to bias. In addition, the participants were asked about their falls on an annual basis rather than using a diary method. Therefore the fall rates data may have been higher than reported, due to poor memory recall of the older participants (as discussed previously).

The following studies were published after the present study had already commenced.

A longitudinal cohort study was conducted by To and colleagues in 2014 on patients aged 50 years and over with bilateral cataract, who were scheduled for cataract surgery at the Eye Hospital in Ho Chi Minh City, Vietnam. Data were collected at three points during the study: 1-week prior to the first eye cataract surgery (baseline), 1-3 months after first/both-eye cataract surgeries (second assessment) and 1-year after each participant's first eye cataract surgery (third assessment). For the baseline and second assessment the questionnaire was administered face to face with the third assessment taking place via a telephone interview. At baseline, participants were asked how many times they had fallen and landed on the floor or ground in the previous 12 months. At the second and third assessment, participants were asked to report how many times they had fallen since their last interview (To et al., 2014).

The prevalence of falls in the year before the first-eye cataract surgery was 13% (53 out of 413). In the year after the first-eye cataract surgery the prevalence of falls was 11% (13 out of 119) for those participants who had their first-eye operated on only (IRR 0.22, 95% CI 0.06-0.77, P=0.018) and 7% (13 out of 193) for those participants who had both of their eyes operated on (IRR 0.17, 95% CI 0.04-0.69, P=0.01) during the follow-up period (To et al., 2014).

This study therefore suggests that first and both-eye cataract surgery significantly reduced the number of falls and injuries in Vietnamese population. Firstly, it is important to note that participants in this study had much poorer vision before surgery than participants in the studies described above, which were conducted in developed countries. This could be one of the reasons that this study found a significant reduction in falls rate post cataract surgery in this Vietnamese cohort. Secondly, the falls data were self-reported and retrospective which could have been affected by recall bias (To et al., 2014).

A retrospective cohort study undertaken by Meuleners and colleagues (2014) compared the number of hospital admissions from injurious falls in adults aged 60 years and over. Data were collected two years before first-eye surgery, between first and second-eye surgery and two years after second-eye surgery.

The risk of an injurious fall that required hospitalisation doubled between first and second eye cataract surgery compared with the two years before the first-eye cataract surgery (RR 2.14, 95% CI 1.82-2.51). This may be due to anisometropia (see

section 3.6.2) experienced by the patients during the waiting period between surgeries. Due to the cost of obtaining new spectacles, some of the patients in the study may have delayed obtaining new glasses until after their second surgery. This meant they had to cope with uncorrected refractive error during the waiting period between surgeries, which increased their risk of falling (Meuleners et al., 2014).
This study also found a significant 34% increase in injurious falls that required hospitalisation in the two years after bilateral cataract surgery compared with the two years before first-eye cataract surgery (RR 1.34, 95% CI 1.16-1.55).

The results from this study differ to those conducted by Harwood and colleagues (2005) and Foss and colleagues (2006) who also investigated the falls risk after first and second-eye cataract surgery. This difference may be because Meuleners and colleagues only investigated hospitalisation falls whereas Harwood and colleagues and Foss and colleagues included all self-reported falls. The participants in Meuleners and colleagues study (2014) were younger including both males and females in the study as opposed to females alone in the Foss and Harwood studies. Foss and Harwood studies were randomised controlled trials in comparison to Meuleners which was a retrospective cohort study.

A study conducted by Tseng and colleagues (2012) investigated the risk of fractures following cataract surgery. This study had two groups: a cataract surgery group that were followed for up to 1-year after the date of their surgery and a cataract diagnosis group that were also followed up to 1-year from the diagnosis date.

The incidence of hip fracture in the cataract surgery group was 1.3% and 1.2% in the cataract diagnosis group. This study found a 16% reduction in the adjusted odds of hip fracture in the cataract surgery group compared with the cataract diagnosis group. The main limitation of this study was the data collected was retrospective and from records (Tseng et al., 2012).

The results obtained from the cataract studies above have shown ambiguous results. A firm conclusion cannot be made as to whether the risk of falls is reduced by cataract surgery. This difference in the results obtained from the cataract studies is due to the different sample sizes used, different populations and different methods used for collecting the data.

5.2. Multifactoral intervention studies

Day and colleagues (2002) compared three interventions to prevent falls in individuals aged over 70 years and living at home: group based exercise, hazard management and vision improvement.

The group-based exercises consisted of weekly exercises over a 15-week period. This was the only group that displayed a statistically significant effect in reducing the annual fall rate. The visual intervention consisted of testing vision and referring the participants to their usual eye care provider if their vision fell below the predetermined criteria. Participants that were randomised to the visual intervention group had a 4.4% reduction in annual fall rates; however, this did not reach statistical significance. This may have been because the number of participants receiving an intervention was very low. Of the 547 participants receiving the vision intervention, 287 were recommended for referral, of which 187 had either recently visited or were about to visit their optometrist or ophthalmologist. Of the remaining 101 participants, only 26 had had some form of treatment (20 had spectacles and 6 had surgery). With such a low number having treatment (5%), it is not surprising that the results for the visual intervention group were not significant (Dhital, Pey and Stanford, 2010).

It was also noted that the control group that did not receive a visual intervention showed an improvement in visual acuity, while those receiving the visual intervention did not. This may be because the advantages of the intervention were explained to the control group for ethical reasons, resulting in the control group obtaining the intervention themselves by visiting an optometrist and having some form of visual intervention. The strongest effect was observed for a combination of all three interventions, producing an estimated 14% reduction in the rate of falls.

5.3. Optometric intervention studies

Cumming and colleagues (2007) conducted a RCT in which a group of 616 community dwellers aged 70 years and over, were randomised to either a control group (n= 307) or an intervention group (n= 309) and prospectively followed up to collate data on falls and fractures they experienced in a 12-month period. The intervention group received the recommended refractive correction. In addition, if deemed appropriate by the optometrist, they received home visits by an occupational therapist or were referred for other ophthalmic problems, such as glaucoma management or cataract surgery. Of the intervention group, 92 received new spectacles, 24 were referred for a home visit, 17 were referred for suspected glaucoma and 15 for cataract surgery. A total of 44% of the intervention group received some form of vision-related treatments. The control group were left to their usual care.

During the 12 month follow up period, it was observed that falls occurred significantly more often in the intervention group (65% fell at least once) than in the control group (50% fell at least once). The falls rate ratio was 1.57 (95% CI 1.20-2.05, P=0.001). Furthermore, there were more fractures in the intervention group (n=31) compared to the control group (n=18). The relative risk was 1.74, 95% CI 0.97-3.11, P=0.06. The findings from this study were completely unexpected and failed to support earlier predictions made by researchers in this study area.

It should be noted that the control group were frailer than the intervention group, had more difficulties with activities of daily living and more frequently used walking aids. It can be assumed therefore, that they spent less time on foot and thus were perhaps less likely to put themselves at risk of falling.

The two groups were however well matched on most of the other risk factors for falls, including the main risk factors of age, gender and history of falls and so the above explanation does not fully clarify the findings. The authors suggested that the control group appeared to obtain optometric care beyond 'the usual' and that there was no difference in visual acuity in the two groups at the 12 month follow up visit (Cummings et al., 2007) when you would expect the intervention group to have better visual acuity.

However, this does not explain the significant increase in the rate of falls in the intervention group. The authors suggested two main possible reasons for their findings. The first was that the intervention participants may have changed their behaviour. For example, perhaps they increased their outdoor activities because of improvements in their visual confidence and put themselves at a greater risk of falling. However, there was no evidence to support this explanation. The second suggestion was that some of the participants received large changes in spectacle prescription and older frail people have greater difficulty adapting to such changes and thus be at an increased risk of falling during this adaptation period. This was supported by the finding that 74% of the intervention group who had major changes in refraction fell at least once, compared with 53% of those who had minor changes.

A major change in refraction was defined as $\geq \pm$ 0.75DS or DC, axis changes of $\geq 10^0$ up to 0.75DC and $\geq 5^0$ for over 0.75DC, any prism change or an induced anisometropia of ≥0.75DS. This latter explanation seems to be the view taken by others. For example, Gillespie and colleagues cite this paper and state that 'older people may be at increased risk of falling while adjusting to new spectacles or major changes in prescription' (Gillespie et al., 2009).

5.3.1. Spectacle adaptation

After cataract surgery, most patients require an updated refractive correction due to significant changes to their refractive error, or they may not need spectacles for distance viewing after the surgery so have obtained a reduction in refractive error during the procedure. A possible cause of difficulties in adapting to new spectacles is a change in spectacle or ocular magnification. This leads to issues regarding magnification and minification once this error is corrected and results in the perception that an object appears to be either further away or closer than it is in reality which could lead to falls. Myopic shifts in refractive correction cause minification and could show the objects to be further away and smaller than anticipated. Hyperopic shifts cause magnification showing objects to be closer and larger (Elliot and Chapman, 2010)

Magnification could also explain the mobility problems encountered by some older adults with updated spectacles and after cataract surgery. Magnification effects with new spectacles require changes to the vestibulo-ocular reflex and associated reflexes (the reflex that links head movements to eye movements, until these are adapted to, the new spectacles seem to make the world 'swim') and astigmatic changes, particularly large and/or oblique can make floors and walls slope. The vestibulo-ocular reflex is discussed in more detail below.

Haran and colleagues (2010) conducted a RCT in which a group of 606 community dwellers, aged 65 years and over, were randomised to either a control group (n=301) or an intervention group (n=305). Participants in the intervention group had an examination by an optometrist. They were then prescribed a pair of single lens distance glasses with recommendations for wearing them for walking and outdoor activities. Participants in the control group had the same optometrist's examination as those in the intervention group. Participants in the control group who needed a prescription change were provided with updated multifocal lenses. The intervention resulted in an 8% reduction in falls (IRR 0.96, 95% CI 0.73-1.16). This study found providing single lens glasses for older wearers of multifocal glasses, who took part in regular outdoor activity, is an effective falls prevention strategy (Haran et al., 2010). It is known that all types of multifocal glasses blur distance objects in the lower visual field, increasing the risk of trip accidents and falls in older people, particularly when outside their homes and when walking up or down stairs (Lord, Dayhew and Howland, 2002).

5.3.2. Visual Function and Balance

Balance control is regulated by three integrated sensory systems; the somatosensory, vestibular and visual. The somatosensory system includes receptors that provide information about pressure distribution, muscle tension, joint angle changes and muscle length changes. The vestibular system is concerned with rotational movements of the head and provides information regarding the body's position, with respect to gravity and movement. The visual system provides information about the size and position of hazards and obstacles in the travel pathway. The visual system contributes about 50% of balance control (Pyykko, Jantti and Aalto, 1990). A disruption to any one of these three balance systems will result in an increased reliance on the other systems to maintain stability (Anand et al., 2003b).

With ageing, there is an increased reliance on visual information for the maintenance of postural stability (Anand et al., 2003b). If the visual system does not adapt to this increased visual reliance then the balance system will be compromised. Therefore, accurate visual information is vital for the maintenance of stable postures in the elderly population. Impaired vision, including that caused by stimulated cataract reduces postural stability, especially if there are disruptions to the vestibular and/or somatosensory systems (Anand et al., 2003a).

Individuals with reduced contrast sensitivity and stereopsis have also shown to have reduced postural stability (Lord and Menz, 2000).

The increased reliance on visual information for the maintenance of postural stability with increasing age has important implications, particularly given the increase in prevalence of visual impairment with advancing age. Age-related changes in the visual system occur even to those individuals who are free from eye diseases (Ivers, 2000). These age related changes in the visual system, along with age related changes in the other two balance systems, can result in impaired balance control in older individuals which can ultimately lead to falls.

5.4. Summary

It was assumed that updating spectacles and performing cataract surgery would reduce the incidence of falls; however the overall assessment of the studies reviewed above surprisingly did not fully support this assumption.

As discussed above, changes in refractive error (post cataract surgery and updating spectacles), causes changes in spectacle magnification, altering the vestibulo-ocular reflex, thus making the world appear to swim. This ultimately may be the cause of increased fall rates during the adaptation period of new spectacles. Therefore, the aim of our study is to determine whether falls are increased due to large changes in spectacle magnification after cataract surgery.

CHAPTER 6

LITERATURE REVIEW: DIZZINESS AND VISION

This chapter will review the literature regarding the prevalence, risk factors and the causes of dizziness. The main risk factor for dizziness reviewed in this chapter is vision. The primary aim of this study was to determine whether cataract surgery improves dizziness and vertigo-like symptoms in an elderly population. The secondary aims were to determine any relationship between dizziness and vertigo-like symptoms and ocular factors such as visual acuity, anisometropia, type of spectacles worn and large changes in spectacle magnification taking into consideration non ocular factors such as age, gender, history of falls, systemic co-morbidity and polypharmacy. This chapter will also review the literature connecting dizziness with falls.

6.1. Defining and Describing Dizziness

Generally speaking, the term dizziness is a vague term encompassing a range of reported symptoms including: light-headedness, feeling off balance, feeling faint (NHS Choices, 2015), experiencing sensations of moving, spinning, floating, swaying etc (Cleveland Clinic, 2014).

Dizziness refers to various abnormal sensations of body orientation and position in space (Sloane and Baloh, 1989). The four categories of dizziness include; vertigo, presyncope, disequilibrium, and other dizziness (Drachman and Hart, 1972). Vertigo is a false sensation that the body or the environment is moving (usually spinning). Presyncope is a feeling of light-headedness that is often described as a sensation of an impending faint. Disequilibrium is a sense of imbalance that is generally described as involving the legs without a sensation in the head. Other dizziness is typically described as vague or floating, or the patient may have difficulty describing the sensation (Drachman and Hart, 1972).

Dizziness is a sensation experienced by people of all ages; however it is most commonly reported by older adults (Maarsingh et al., 2010a). Due to the fact that dizziness can lead to falls and injuries (Tinetti et al., 2000, Black and Wood, 2005, Rubenstein, 2006) it is quite common for people, the elderly in particular, to develop a fear of dizziness which can have a limiting effect on their daily activities (WebMD, 2015).

6.2. Prevalence of Dizziness

Dizziness is prevalent amongst the adult population, causing considerable morbidity and utilisation of health services. The reported prevalence ranges from 13 to 38%, depending on the definition used and the population studied (Yardley et al., 1998, Tinetti et al., 2000, Stevens et al., 2008, Maarsingh et al., 2010a).

6.3. Dizziness ascertainment

In the majority of the studies pertaining to dizziness, a general question is asked about the presence of any dizziness, for example, 'Are you troubled by vertigo, dizziness, disturbed balance or general unsteadiness?' (Johnsson et al., 2004). If the patient implies that they suffer from dizziness then more questions are asked about the dizziness.

The most commonly used and accepted questionnaire to quantify the impact of dizziness on everyday life is the Dizziness Handicap Inventory (DHI) yet despite this its structural validity is not established (Duracinsky et al., 2007). This study used a self-reported questionnaire, the short form of the Dizziness Handicap Inventory (DHIsf) scale, which was validated using Rasch analysis (Jacobson and Newman, 1990, Tesio et al., 1999). The DHIsf comprises of 13 questions, each with a yes/no answer and a participant with a score of 13 has no handicap from dizziness whereas a score of zero would indicate extreme handicap.

6.4. Causes of dizziness

In many earlier studies, it was assumed that dizziness was a symptom of one or more discrete diseases. The diagnostic findings from these studies have varied greatly, for example, vestibular disease was identified as a primary contributing cause in 4% to 64% of cases of dizziness (Tinetti et al., 2000). Similarly, cerebrovascular causes were identified in 0% to 70% of cases, psychiatric cases 0% to 40%, and cervical spondylosis in 0% to 66% (Tinetti et al., 2000). The frequency with which no diagnosis could be made has ranged from 8% to 22% of cases, whereas multiple diagnoses have been assigned in 0% to 85% of cases (Tinetti et al., 2000). The differences in findings amongst these studies are probably due to the different populations studied and the different criteria used in assigning diagnoses. These discrepancies do however suggest that considering dizziness solely as a symptom of discrete diseases may not be the optimal clinical strategy. The disparity in the causes of dizziness identified among these studies, combined with the fact that the majority of these dizzy patients had multiple possible causes, all suggests that dizziness might be considered a geriatric syndrome with multiple predisposing risk factors (Kao et al., 2001). In recent community-based studies, dizziness has been found to be associated with numerous risk factors including: anxiety, depressive symptoms, impaired balance and gait, past myocardial infarction, postural hypotension, the use of five or more medications, impaired hearing, female sex, abnormal heart rhythm, cataracts and self-reported poor vision (Tinetti et al., 2000, Stevens et al., 2008, Maarsingh et al., 2010b, Kao et al., 2001)

6.5. Dizziness and vision

A community based controlled study conducted by Colledge and colleagues (1996) compared participants suffering from dizziness (n=149) with a control group of participants with no symptoms of dizziness (n=97). They found that the group containing dizziness sufferers (Group 1) were significantly more likely to have eye diseases ($p<0.001$) than the control group. However, the eye diseases information was taken from the medical records which may not have been up to date with the current status of their eye health at the time the study was conducted. In this study, poor vision was defined as visual acuity less than 6/9 in both eyes. In Group 1, 15% of the participants had poor vision compared to only 4% in the control group ($p=0.015$). Out of the 149 patients in Group 1, no patients were thought to be suffering from dizziness due to poor vision alone. However in those 15% of participants with poor vision, poor vision was thought to be a contributing factor for the dizziness. The study overall concludes that poor vision often accompanies dizziness but is rarely the sole cause.

Kao and colleagues (2001) cross-sectional study involved 54 patients who had reported dizziness and 208 who had not all aged 60 years and over. Their aim was to determine whether there was a link between the identified risk factors (mentioned above) and dizziness. They found cataracts to be independently associated with dizziness with an odds ratio of 5.3 (95% CI 2.2-12.9). However, limited information is provided about these patients with cataracts as to whether they had cataract in one eye or both, or whether they had the cataracts operated on or not. The information was extracted from their medical history so may not have been up to date at the time of the study. Visual acuity was measured in this study using a Snellen eye chart. Of the 54 dizzy patients, 8 of them had a visual acuity of 6/18 or worse and of the 208 non dizzy patients, 13 had a visual acuity of 6/18 or worse, however this was not found to be statistically significant (P=0.37).

The aim of Stevens and colleagues (2008) longitudinal study was to identify risk factors associated with self-reported dizziness. The required data were extracted from the English Longitudinal Study of Ageing (ELSA) which contained data for 2,295 participants' aged 65 years and over. Out of the 2,295 participants, 375 self-reported dizziness and 2,550 did not. In this study, poor vision was based on the participants self-reporting whether they perceive their vision to be good or poor, which makes it difficult to compare with others as each definition of poor vision was purely subjective. This study did find an association between self-reported poor vision and dizziness with an odds ratio of 1.72 (95% CI, 1.23-2.39).

Patients aged 65 and over visiting their general practitioner because of dizziness were identified (N=3,990) by Maarsingh and colleagues (2010a). Data were obtained from the Second Dutch National Survey of General Practice, a prospective study which took place over a 12-month period in 2001. 46611 patients did not report any dizziness. Vision data was extracted from medical records. A definition of impaired vision in this study was not given. 1% of dizzy patients had impaired vision compared to 0.6% of non-dizzy patients. This was found to be statistically significant (P=0.006). Cataract information was also extracted from the patients' medical records, however as in the study above, little information is provided as to whether they had cataract in one eye or both, or whether they had had the cataract operated on or not. From the medical records, 3.7% of the dizzy patients had cataract compared to 2% of non dizzy patients. This was reported to be statistically significant (P<0.001).

It is evident in these studies that a link between vision and dizziness may exist, although there are flaws in the methodology of these studies and the data are therefore inconclusive. Tinetti and colleagues (2000) found no significant difference in visual impairment in dizzy and non-dizzy groups. Maarsingh and colleagues (2010b) conducted a cross-sectional study; patients's aged 65 years and over consulting their general practitioner for dizziness were invited to take part in the study. In this study visual acuity was measured by means of a well lit-eye chart with Landolt rings. The researchers excluded participants with severe visual impairment, defined in this study as corrected visual acuity of less than 3/60 in the best eye. From the medical records, 48% had a history of cataract. However, only 1% of participants had poor vision as a minor cause of dizziness and this was found not to be statistically significant. Menant and colleagues (2013) conducted a secondary analysis of a prospective cohort study involving 516 community-dwelling adults aged 73 to 92. A definition of visual impairment was also not given in this study. No significant difference in visual impairment between the dizzy group (35%) and the non dizzy group (30%) was found. Contrast sensitivity in this study was measured using the Melbourne Edge Test and no difference in contrast sensitivity was found between the dizzy and the non dizzy group.

6.6. Dizziness and falls

Currently, there is little literature available linking dizziness with falls. A prospective cohort study was conducted by Menant and colleagues (2013) that looked into the relationship between dizziness and falls. Five hundred and sixteen community dwelling older adults, aged between 73 to 92, participated in the study. Falls data were collected prospectively using monthly diaries. Participants were categorized into dizzy and non-dizzy groups based on self-reporting of dizziness, vertigo and light-headedness (Menant et al., 2013). Participants were asked to complete questionnaires relating to their health and physiological well-being and under-went a tilt table blood pressure test, the Physiological Profile Assessment (PPA) and leaning balance test (Menant et al., 2013). Fifty-one dizzy participants (23%) and forty-five (15%) non-dizzy participants experienced multiple falls in the follow-up period. Dizziness increased the risk of multiple falls in an unadjusted analysis (RR=1.55, 95% CI = 1.08-2.23). Neck and back pain was the strongest mediator identified, leading to an 8% reduction in the RR between dizziness and multiple falls (from RR=1.55 (univariate) to RR=1.43 (multivariate). These findings suggest that, regardless of their sensorimotor and balance function level, older people who report dizziness or light-headedness are at a greater risk of recurrent falls, possibly due to neck, back pain and anxiety (Menant et al., 2013).

One major limitation of this study is the dizziness question used, 'Since the age of 60 years, have you suffered from the following symptoms: (i) dizziness or vertigo; and (ii) light-headedness when standing up from a seat or bed?' the breadth of the dizziness question and long time period may have resulted in higher reporting of dizziness in this study. Another study conducted by Moller and colleagues (2013) investigated the prevalence and predicator of falls and dizziness. This study found specific factors such as neuroleptics, visual acuity and feelings of nervousness as important factors in predicting falls and dizziness, however they did not investigate if there was any link between dizziness and falls.

It is evident that limited literature is available linking dizziness and falls, further investigation needs to be carried out before a firm conclusion can be made as to whether or not a link exist.

6.7. Summary

The literature currently available linking vision as a risk factor for dizziness is limited therefore conclusive links cannot be made at the present time. The major flaw with most of the studies discussed above is the collection of visual information from medical records which may not be up to date. This can result in inconsistencies with the actual vision of the participant at the time of the reporting of dizziness. It is in the interest of optometric professionals to provide richer visual data. Therefore this study aims to determine whether symptoms of dizziness and vertigo are associated with factors such as visual acuity, anisometropia, type of spectacles worn and with large changes in spectacle magnification and falls.

CHAPTER 7

METHODOLOGY

This chapter provides a detailed description of the methodology used in the present study. Inclusion and exclusion criteria are explained in addition to how various aspects of data relating to demographics, medical issues, vision, falls and dizziness were collected. It describes the ethical considerations undertaken for this study including; ethical approval needed for this study (granted by the National Research Ethics Service (NRES) Committee of the East of England), the required consent from the participants and the confidentiality issues in connection with the handling of participants' personal data.

7.1. Aims of the study

The primary aim of this study was to determine whether cataract surgery had a significant effect on post-operative fall rates and symptoms of dizziness.

The secondary aims of this study were to determine whether ocular factors listed below had a significant effect on post-operative fall rates and symptoms of dizziness:

(vi) Large refractive correction changes post surgery (Cumming et al., 2007).

(vii) Increased anisometropia after first eye cataract surgery (Meuleners et al., 2014).

(viii) Changes in refractive magnification post surgery increasing the risk of trips on steps and stairs (Elliott and Chapman, 2010).

(ix) Changes in types of spectacles worn post surgery (Haran et al., 2010).

(x) Increased confidence leading to greater outdoor activity leading to increased falls rate (Cumming et al., 2007).

7.2. Study Design

A cohort study was undertaken to assess the falls rate and the degree of handicap caused by dizziness before and after uncomplicated cataract surgery.

7.3. Ethical Considerations

7.3.1 National Research Ethics Service (NRES)

The study was granted ethical approval by NRES committee of the East of England in May 2012 for Bradford Royal Infirmary (BRI) and in March 2013 for Yorkshire Eye Hospital (YEH). For this study to take place at BRI, approval was also granted from the BRI Research and Development Team in June 2012.

7.3.2. Consent

Potential participants were given as much time as they needed to complete the forms (see section 7.4) and return them to us in the pre-paid envelopes. This gave the patients sufficient time to contact the research team about the study if further information was required, or to discuss their participation with their family members, so that consent was fully considered before consenting. The minimum time period of 24 hours for obtaining consent was adhered to.

Patients were informed that they were under no obligation to take part in this study and if they decided that they wanted to withdraw, they could do so without giving a reason and this would not affect the standard of care they would receive at BRI/YEH in any way. They were also made aware of their option to withdraw from the study at any time. If they decided to withdraw, all their identifiable data collected up until the point of withdrawal were retained and used in the study, but no further data were collected on that participant.

7.3.3. Confidentiality of personal data

To ensure confidentiality, data collected about the participants were stored on a University (password protected) computer spreadsheet under their Unique Identification Code (UIC, see section 7.4). Their personal contact information was stored in a separate spreadsheet with the same level of security for access. The passwords to these documents were not written down and were only known by the Chief Investigator and the PhD student, who collected and analysed the data. During the study, hard copies of the data were stored in a locked filing cabinet in a private office in the Richmond Building, University of Bradford. Personal data remained in storage for up to six months after which it was securely disposed of as confidential waste.

7.3.4. Communication

A large proportion of the patients were unable to adequately understand written English, these participants were advised that they could complete the questionnaire with the help of family/friends if they wished. If this was not possible, the willing participants had the option of contacting the study team, and have the documents translated in the requested language. This is equivalent to the standard practice for patients who need assistance in communicating when attending NHS appointments and/or attending appointments in a private eye examination setting.

7.4. Methods:

Patients aged 65 years and over, undergoing age-related cataract surgeries in one or both eyes, at Bradford Royal Infirmary (BRI) and Yorkshire Eye Hospital (YEH) were sent details about the study. The head optometrists and member of the direct care team at BRI and YEH identified potential participants from the computerised cataract waiting lists. On identification, the patients were sent the following documents:

i. An invitation letter (Appendix A.1).
ii. A detailed participant information sheet about the study (Appendix A.2).
iii. A consent form (Appendix A.3).
iv. A retrospective falls diary (Appendix A.4).
v. A Dizziness Handicap Inventory (DHI) questionnaire (Appendix A.5).
vi. Spectacle questionnaire (Appendix A.6).
vii. General questionnaire (Appendix A.7).
viii. A pre paid return envelope.

All the documents were constructed so they were easily understood by the lay-person. The forms that required participants to complete were designed to obtain all the required information whilst minimising the burden being placed on the participants. They were also written in large print as it was anticipated that many of the participants may have impaired vision by virtue of their condition.

In order to maintain confidentiality, each participant was assigned a Unique Identification Code (UIC). This code was recorded in a spreadsheet against their demographics data including: their date of birth, gender, ethnicity and BRI/YEH identification code. This enabled us to keep a clear record of the patients that had been contacted about the study, which could then be linked to their confidential information i.e. names and addresses once their consent had been obtained. Due to patient confidentiality, their personal information was only available on BRI's/YEH's computer systems and so this identification procedure was necessary to connect their personal information to their UIC upon each visit to the hospital at the pre-consent stage. The involvement of the residential head optometrists at the selection stage aimed to ensure full compliance with the NHS regulations regarding patient confidentiality.

7.5. Participant Recruitment

7.5.1. Inclusion Criteria

Participants were recruited between the 1st of July 2012 and the 31st of July 2013 from Bradford Royal Infirmary and between 5th of March 2013 and the 31st July 2013 from Yorkshire Eye Hospital. Inclusion criteria included aged 65 years and over, awaiting surgery for age-related cataract of any type in one or both eyes. The patients were placed on the waiting list only if the ophthalmologist deemed that the cataract surgery would benefit the overall visual outcome of the patient despite any other age-related eye diseases they may have.

7.5.2. Exclusion Criteria

Those who consented to participate but who subsequently suffered from severe surgical complications, recorded by the ophthalmologist in their medical records were excluded from the study.

The treating Ophthalmologist was only able to release the medical notes for review at the post operative stage after patient consent was received. This created a barrier to accessing the information needed to exclude potential participants until the end of the study.

7.6. Baseline Data

7.6.1 Demographic Data

Participants' age, gender and ethnicity were obtained using the computer systems at BRI/YEH. Information about participants' home environments, including factors known to be related to falls at home, such as stairs and co-residence was obtained using the general questionnaire (See Appendix A.7). Information about the participants' activity levels was also obtained from the general questionnaire.

7.6.2. Medical Data

Information regarding general health status and the number and type of prescribed medications were obtained from the participants' medical records by the study team after consent was provided by the participants. The British National Formulary (BNF) was used to check the side effects of medications.

7.6.3. Visual Data

Participant's pre-operative and post-operative habitual refractive correction (i.e. the spectacles they were usually wearing for distance tasks) was obtained from their hospital records. If the requisite refractive correction data was missing from the hospital records, it was obtained from the participants' optometrist, subject to obtaining their consent. If this was unavailable, the information was determined via focimetry of the participants' spectacles at Bradford University Eye Clinic by the PhD student. The type of spectacles worn (Varifocals, Bifocal, single vision distance and/or near or none) before and after surgery was obtained from the general questionnaire for those patients that had both their eyes operated on during this study. A spectacle questionnaire was issued to them post first eye operation so that type of spectacles worn during this stage was known.

7.6.4. Falls Data

A consensus statement from the Prevention of Falls Network Europe (ProFaNE) recommended that a fall should be defined as "an unexpected event in which the participants come to rest on the ground, floor, or lower level'' (Lamb et al., 2005). Including the lay persons' perspective, ProFaNE suggested that in falls studies all participants should be asked "have you had any fall including a slip or trip in which you lost your balance and landed on the floor or ground or lower level?''(Lamb et al., 2005). This was the definition used in this study (see section 2.1, on falls definition).

At the beginning of the study, participants were asked to complete a general questionnaire (see Appendix A.7.). One of the questions asked each participant to report details of any falls they had experienced in the six months prior to completing the questionnaire. In an attempt to improve the accuracy of the falls data, participants were also sent monthly falls diaries in the period after consent was given to participate and before surgery (1-3 months).

Self-reported 6-months falls data were collected in the same way post-operatively: participants were sent monthly falls diaries for completion 1-3 months (equivalent to the number of completions pre-surgery) to ensure a fair comparison of falls data pre and post-surgery. Then at six months post cataract surgery, participants were sent the general questionnaire again and asked to provide information on any falls they had had in the last six months. The response to the question regarding falls in the last 6 months was checked against the falls diaries information and any inconsistencies were investigated.

McGwin and colleagues (2006), stated that if the follow up period extends beyond the optimum of six months post surgery, there is a higher chance that any post operative reduction in falls after six months, may be overridden by age related increases in the risk of falling, even to the extent that that they may overcome the benefits of surgery. Therefore, the six months follow up period post surgery was chosen for this study.

If the participants did not respond after two weeks of being sent each falls diary, they were contacted by telephone, encouraged to respond and asked if they would like another copy of the diary. If there was still no response the participant was excluded from the study. All patients that reported falling were asked to give further information including the number of falls that had occurred, whether they were wearing spectacles at the time of each fall and whether they suffered any injuries as a result of each fall (See falls diary, Appendix A.4).

7.6.5. Dizziness Handicap Inventory (DHI) Data

The most commonly used and accepted questionnaire to quantify the degree of dizziness and vertigo-like symptoms is the Dizziness Handicap Inventory (see Appendix A.5) yet despite this its structural validity is not established (Duracinsky et al., 2007). In this study, participants were sent a copy of the short form of the dizziness handicap inventory (DHIsf), which has been validated using Rasch analysis (see section 6.3).The DHIsf comprises 13 questions, each with a yes/no answer. A participant with a score of 13 has no handicap from dizziness and vertigo-like symptoms whereas a score of zero would indicate extreme handicap. Participants were asked to complete the DHIsf with regards to any dizziness symptoms they had suffered in the previous month. The participants were required to complete the DHIsf at the beginning of the study and one month post-surgery, a second copy of the DHIsf was issued to assess the effect of surgery on any dizziness symptoms (after the second eye for those participants that had surgery on both eyes).

7.7. Sample Size

The Ophthalmology department at BRI perform cataract surgery on just over 200 patients per month. The intention for this study was to recruit 280 patients in a 13 month period (~12% recruitment rate assuming recruitment of 312 to allow a 10% drop-out rate), which previous studies suggested was readily achievable.

The required sample size of 280 was calculated using Peduzzi and colleagues (1996) formula of N=10k/p, where k is the number of covariates accounted for and p is the likely proportion of positive cases. The following seven covariates were accounted for; age, female gender, problems with mobility, living alone, number of chronic conditions (3 or more), taking four or more medications (poly-pharmacy) and the use of tranquillizers or sedatives. These seven covariates accounted for are the major causes for both dizziness and falls in an elderly population (Tinetti et al., 1988, Campbell et al., 1989, Nevitt et al., 1989, Hornbrook et al., 1994, Ivers et al., 1998, Elliott, Painter and Hudson, 2009, Gassman et al., 2009, Tamber & Bruusgaard, 2009, Maarsingh et al., 2010). The likely proportion of positive cases for patients reporting dizziness or vertigo-like symptoms was estimated at the middle of the reported range at 25% (Colledge et al., 1994, Gassmann et al., 2009, Tamber and Bruusgaard, 2009) patients' falling was also estimated at the reported range at 25% (Nevitt et al., 1991, Tinetti et al., 1995, Lord et al., 2007).

1,240 recruitment packs, were posted to potential participants and 364 agreed to participate in the study. The recruitment rate for this study was 29% a lot higher than that reported above. Seventy-seven were excluded from the analysis. The drop-out rate for this study was higher at 21% than the 10% estimated drop-out rate above. Therefore over the same 13-months estimated period for recruitment, more participants were recruited, however with the higher dropout rate the final number of participants that took part in this study was 287, the target sample size being 280 so overall the required number of participants was achieved for this study.

CHAPTER 8

RESULTS

This chapter presents all the data collected in the manner described in Chapter Seven and provides a detailed analysis of the findings relating to dizziness and falls.

8.1. Statistical Analysis

For analysis, all the data were added to an excel spreadsheet. Data analysis was then carried out using STATA, version 13.1. The excel spreadsheet contained the following data:

1. Participants general information

Each participant's Unique Identification Code (see section 7.4) was placed on to the analysis spreadsheet against their age and gender.

Participants' activity levels were based on a simple question about their outdoor activity before and after the study (see General Questionnaire, Appendix A.7: Question 4). In this study, the activity levels data were found to be highly skewed using the Kolmogorov-Smirnov test, therefore the participants were dichotomised into those who were active (active group) and those who were inactive (inactive group). If the participant ticked never, seldom or walked a couple of times a month, when answering the question 'How often do you walk outside for half an hour?' then they were grouped into the inactive group. However, if they ticked they walked outside every day or a couple of times a week they were grouped into the active group.

The change in activity limitation post surgery for each participant was classified into more active, less active or no change in activity limitation post surgery (Three-point scoring system, see table 8a).

Table 8a: Three-point scoring system for the change in activity limitation

Activity limitation before surgery	**Activity limitation after surgery**	**Code**
Active	Active	0
Inactive	Inactive	0
Inactive	Active	1
Active	Inactive	-1

Information about participants' home environments, including factors known to be related to falls at home, such as stairs and co-residence was obtained using the general questionnaire (See Appendix A.7: Question 1 and 2) and placed on to the spreadsheet. If the participants had stairs at home a code of 1 was noted and a code of 0 was given to those participants who did not have stairs at home. If the participant was living with someone a code of 1 was given and a code of 0 was given to those participants that lived alone.

2. Medical Data

The number of chronic conditions and the number of medications taken by each participant was obtained from the participants' medical records and added to the spreadsheet. Those participants taking four or more medications (Rubenstein, Josephson and Robbins, 1994) were identified with a code of 1 on the spreadsheet. Those participants taking sedatives (Rubenstein, Josephson and Robbins, 1994) were also identified and given a code of 1 on the spreadsheet with a code of 0 for the participants not taking sedatives.

Information regarding the participants' general health was also obtained from the participants' medical records. If the participant suffered from arthritis and/or anxiety they were given a code of 1 and a code of 0 if the participants did not have these medical conditions. Participants suffering from hypertension were given a code of 1 on the spreadsheet and a code of 0 for those participants that did not suffer from hypertension. Lastly, participants with diabetes where identified and given a code of 1 on the spreadsheet, with a code of 0 to those participants that did not suffer from diabetes.

3. Visual Data

The participants were categorised into three groups depending on the cataract surgery they received during the study period; those participants who had a cataract operation in the first eye or their second eye or both eyes. This information was extracted from the computerised cataract waiting lists at BRI and YEH.

The type of spectacles (none, single vision, multifocals) the participants wore for walking around before and after their surgeries (as self-reported from the general/spectacle questionnaire, see Appendix A.6/A.7) were recorded on the spreadsheet. The change in spectacle type post surgery was recorded on a three-point and a five-point scoring system. On the three-point scoring system (see Table 8b), no change in spectacle type was given a code of 0. A code of 0 was also given to those participants that wore single vision spectacles before surgery but then did not wear any glasses after surgery or vice versa. A code of 1 was given to participants that changed from multifocals to single vision or no spectacles post surgery. A positive code value was given to these participants, since they are no longer wearing multifocals post-surgery, reducing the risk of falling (see section 5.3.1). A code of -1 was given to participants that wore single vision/no spectacles before surgery but then wore multifocals after surgery. A negative code value was given to these participants as multifocals have been found to be a risk factor for falls (Haran et al., 2010), as these participants were placed into multifocals post-surgery they have a greater risk of falling, hence a negative code was given (see section 5.3.1).

Table 8b: Three-point scoring system for the change in spectacle types.

Type of spectacles worn before surgery	**Type of spectacles worn after surgery**	**Code**
No spectacles worn or single vision or multifocal spectacles	Same spectacles type worn	0
No spectacles worn	Single vision spectacles	0
Single vision spectacles	No spectacles worn	0
No spectacles worn or single vision spectacles	Multifocal spectacles	-1
Multifocal spectacles	No spectacles worn or single vision spectacles	1

The visual acuity and refractive correction data were assigned to the 'best' and 'worst' eye, rather than operated and non operated eye as binocular vision function is typically related to the vision in the best eye (Rubin et al., 2000).

The Snellen visual acuity measurements taken before and after surgery and taken from the ophthalmology clinical records were all converted into LogMAR and placed on to the spreadsheet for analysis.

The participants' habitual refractive correction (i.e. their spectacle prescription worn when walking) was converted into power vector format (Thibos et al., 1997) to enable a comparison of data before and after surgery.

The overall change in both spherical correction and astigmatism was considered, but not the direction of the change (i.e. it was assumed that in terms of their effect on dizziness and falls, a 6.00DS reduction in hyperopic correction would have a similar effect as a 6.00DS myopic reduction and a 1.00DC swing towards against-the-rule astigmatism would be similar to a 1.00DC swing towards with-the-rule astigmatism), for this reason the absolute value of the changes due to cataract surgery in Mean Sphere Equivalent (MSE) and the vector values for astigmatism J_0 and J_{45} were used in the analysis, along with the absolute change in anisometropia.

Changes in refractive correction from second eye surgery were used in the analysis of patients who underwent surgery in both eyes as falls were assessed after second eye surgery for those patients.

4. Falls and Dizziness data

If the participant fell before the surgery and/or after the surgery a code of 0 was given for no falls and a code of 1 was given if a participant fell.

A comparison of the DHIsf scores before and after cataract surgery was carried out using the Wilcoxon signed rank test for dependent samples. As the dizziness scores were found to be highly skewed using the Kolmogorov-Smirnov test (see Figure 8a) participants were dichotomised into those who scored 13 on the DHIsf and having no handicap from dizziness (the non-dizzy group), and those who scored less than 13 on the DHIsf and have some level of handicap from dizziness (the dizzy group).

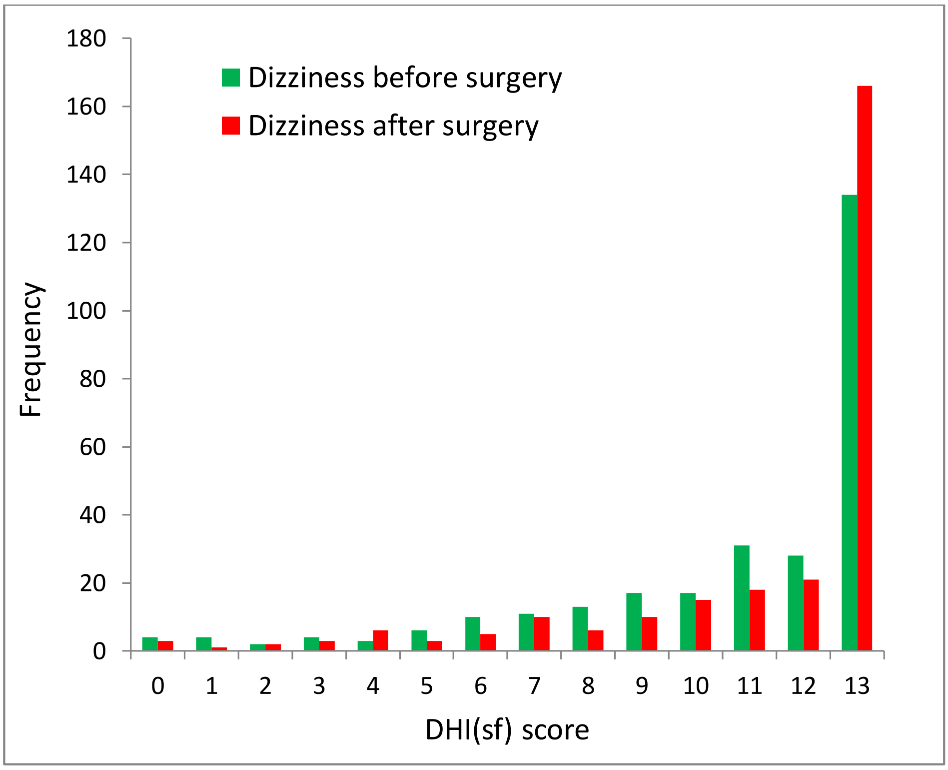

Figure 8a: Histogram to show the distribution of the Dizziness Handicap Inventory (short form) scores before and after surgery.

8.2. Falls Results

1,240 recruitment packs were posted to potential participants and 364 agreed to participate in the study. 77 were excluded from the analysis. A breakdown of the reasons for exclusion is shown in Figure 8b. The final number of participants that took part in this study was 287. This is similar to the recruitment rate in the earlier UK cataract surgery studies (Harwood et al., 2005, Foss et al., 2006). Differences between demographic data for included and excluded participants were analysed using the Mann-Whitney U test for continuous data and the chi-square test for categorical data. There was no significant difference in age (U=10245, p=0.33) or sex (χ^2 = 0.11, p=0.80) between those included (age 77years, 55% females) and those excluded (age 74 years, 53% females) from the study. Of the 287 patients completing the study (mean age 76.5±6.3years; 55% females; 93% Caucasian), 81 (28%) had routine cataract surgery in the first eye, 109 (38%) in the second eye and 97 (34%) had surgery in both eyes. The latter group were those patients in whom there was less than 6 months between first and second eye surgery (median 57 days, IQR 43-81 days) due to this, 6-month falls data between surgeries was not possible to collect. For these participants, a post-operative falls rate was collected for the 6-month period after their second eye surgery.

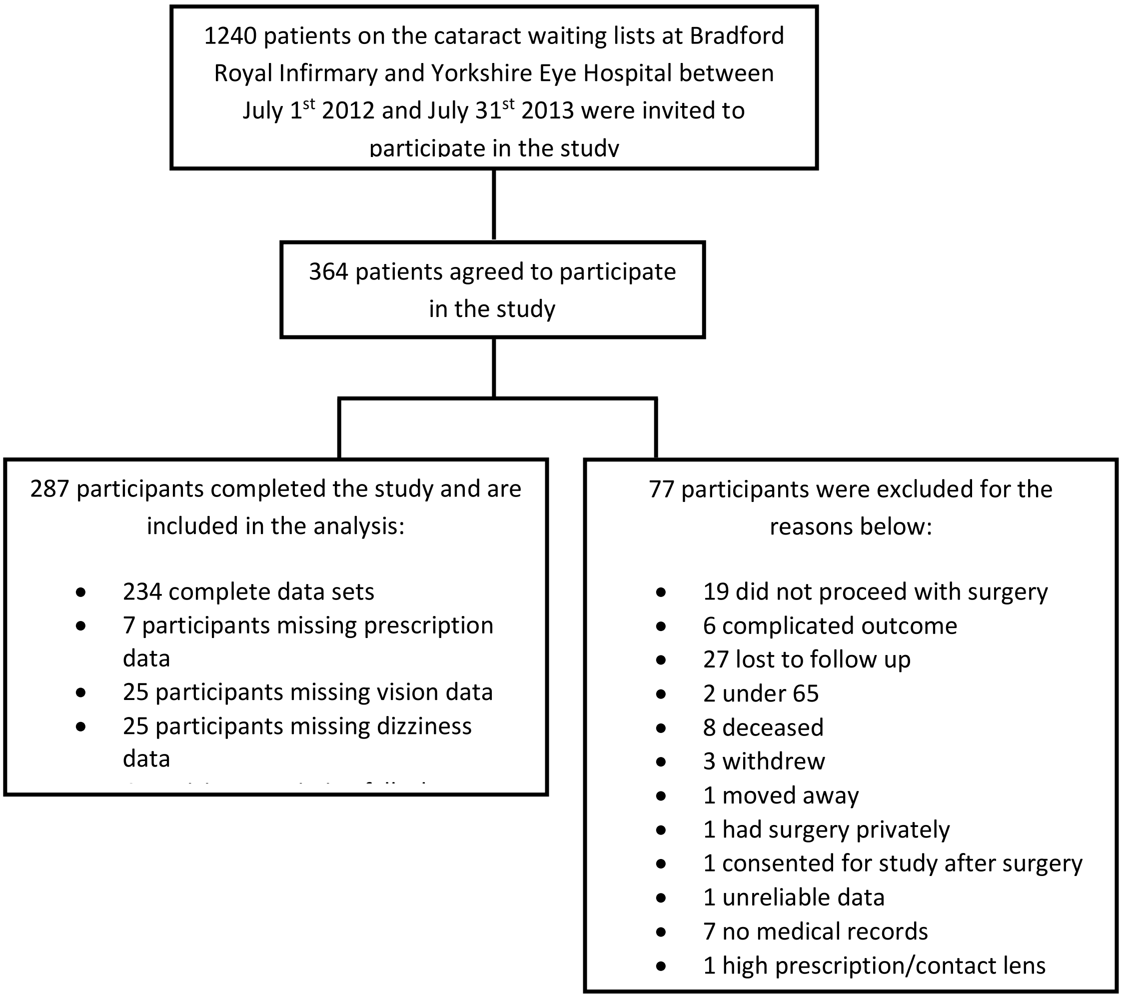

Figure 8b: A breakdown of the reasons for participant exclusion.

The self-reported 6-month falls rate remained similar before and after cataract surgery (χ^2= 0.87, p=0.35), with 66 out of 287 (23%) of the participants reporting falling in the 6 months prior to surgery compared to 56 out of 283 (20%) that reported falling in the same period after surgery. 36 participants fell less after surgery than before; 28 participants fell more after surgery than before and the remaining 219 did not change. This was similar for all three types of surgery (first eye surgery, 23% vs. 20%; second eye surgery, 24% vs. 19% and surgery on both eyes, 22% vs. 21%). Median and (IQR) refractive correction and habitual VA data before and after cataract surgery for the operated and non-operated eye are provided in table 8c. This will be discussed further in Chapter 9.

The pre-operative medical data for the fallers and non-fallers is shown in table 8d. The fallers appear to be frailer than the non fallers, with the number of participants with arthritis in the fallers group being greater than the number of participants in the comparable non-fallers group (χ^2=6.34, p=0.01). The number of participants taking four or more medications (polypharmacy) is also greater in the fallers group than the non-fallers group (χ^2=5.52, p=0.02). The number of participants taking sedatives is also higher in the fallers group than the non-fallers group (χ^2=7.20, p=0.01). A greater number of fallers suffer with dizziness compared to non-fallers (χ^2=20.66, p<0.001)

The post-operative medical, dizziness and falls data for the fallers and non fallers is also shown in table 8d. The number of participants with pre-operative falls in the fallers post-operative group was greater than in the non-fallers post-operative group (χ^2=51.03 p=0.001). A greater number of post-operative fallers suffer with dizziness compared to the post-operative non-fallers (χ^2=11.07, p=0.001).

Table 8c: Median (inter-quartile range) pre and post-operative absolute values of refractive correction and visual acuity for 287 patients before and after cataract surgery in the operated and non-operated eye. Changes in the non-operated eye are typically due to changes in spectacle wear. **Key: MSE:** mean spherical equivalent in dioptres; **J_0 and J_{45}:** Vector values of astigmatism in the ordinal and oblique meridians respectively; **Habitual VA:** monocular visual acuity (logMAR) in the operated and non-operated eyes measured with the patients' own distance spectacles if worn.

	Operated Eye		**Non-Operated Eye (1st eye surgery)**		**Non-Operated Eye (2nd eye surgery)**	
	Pre-Op	**Post-op**	**Pre-Op**	**Post-Op**	**Pre-Op**	**Post-Op**
MSE (D)	1.25 (0.00-2.88)	0.00 (0.00-0.50)	1.38 (0.00-2.25)	0.00 (0.00-1.34)	0.00 (0.00-0.50)	0.00 (0.00-0.38)
J_0 (D)	0.13 (0.00-0.48)	0.00 (0.00-0.31)	0.13 (0.00-0.48)	0.00 (0.00-0.28)	0.00 (0.00-0.19)	0.00 (0.00-0.39)
J_{45} (D)	0.07 (0.00-0.27)	0.00 (0.00-0.13)	0.04 (0.00-0.19)	0.00 (0.00-0.08)	0.00 (0.00-0.19)	0.00 (0.00-0.16)
VA	0.30 (0.20-0.40)	0.10 (0.00-0.24)	0.20 (0.10-0.28)	0.24 (0.10-0.80)	0.20 (0.00-0.26)	0.10 (0.00-0.24)

Table 8d: Pre-operative and post-operative data for the fallers and non-fallers

	Pre-op fallers N=66	**Pre-op non-fallers N=221**	**Chi-squared/ Mann Whitney U and p-value**	**Post-op fallers N=56**	**Post-op non-fallers N=227**	**Chi-squared/ Mann Whitney U and p-value**
Age (Mean±SD)	78.1± 6.6	76.0± 6.1	U=5853.00 $p = 0.015$	78.3± 6.8	76.1± 6.1	U=5083.50 $p = 0.013$
Sex (% F)	65	52	$\chi^2 = 3.30$ $p = 0.09$	61	55	$\chi^2 = 0.46$ $p = 0.58$
Dizzy (%)	76	44	$\chi^2 = 20.66$ $p < 0.001$	54	30	$\chi^2 = 11.07$ $p = 0.001$
Pre-op falls (%)	*	*	*	59	14	$\chi^2 = 51.03$ $p < 0.001$
Polypharm (%)	70	53	$\chi^2 = 5.52$ $p = 0.02$	64	55	$\chi^2 = 1.56$ $p = 0.23$
Arthritis (%)	35	20	$\chi^2 = 6.34$ $p = 0.01$	32	21	$\chi^2 = 3.32$ $p = 0.07$
Sedatives (%)	21	9	$\chi^2 = 7.20$ $p = 0.01$	16	11	$\chi^2 = 1.32$ $p = 0.35$
Anxiety (%)	14	4	$\chi^2 = 9.15$ $p = 0.002$	9	5	$\chi^2 = 1.06$ $p = 0.34$
Diabetes (%)	21	25	$\chi^2 = 0.47$ $p = 0.49$	27	24	$\chi^2 = 0.10$ $p = 0.87$
High Blood Pressure (%)	50	53	$\chi^2 = 0.18$ $p = 0.78$	52	52	$\chi^2 = 0.001$ $p = 1.00$
Activity Limitation (Active group %)	80	88	$\chi^2 = 2.72$ $p = 0.1$	80	84	$\chi^2 = 0.36$ $p = 0.55$

Table 8e: The data for all the four falls groups

	Falls pre-op to no falls post op (N=32)	No falls pre or post surgery (N=195)	Pre-op no falls to post-op falls (N=23)	Falls pre and post surgery (N=33)	P-values
Age (Mean±SD)	77.8±6.7	75.8±6.0	78.0±7.0	78.5±6.7	p=0.012
Sex (% Females)	75	52	65	58	p=0.200
Dizziness pre-op (%)	69	44	48	82	p=0.001
Dizziness post-op (%)	56	26	30	70	P<0.001
Polypharm (%)	69	53	57	70	p=0.320
Arthritis (%)	25	20	17	61	p<0.001
Sedatives (%)	19	9	9	21	p=0.890
Anxiety (%)	13	4	0	15	p=0.040
Diabetes (%)	22	25	35	21	p=0.190
High Blood Pressure (%)	56	51	65	42	p=0.160
Active Group pre-op (%)	84	88	87	76	p=0.790
Active Group post-op (%)	81	84	83	79	p=0.980

Table 8e illustrates the medical, dizziness and falls data for the four groups. The four groups being; the participants that fell pre-operatively but not post-operatively (Group 1, N=32), the participants that did not fall pre or post operatively (Group 2, N=195), the participants that did not fall pre-operatively but fell post operatively (Group 3, N=23) and the final group with participants that fell pre and post surgery (Group 4, N=33). This will be discussed further in Chapter 9.

The number of patients wearing spectacles for distance viewing (walking around spectacles) was reduced after surgery (from 196/287, 68% to 147/285, 52%; Fishers exact test, p<0.0001). The association between falls and changes into and out of multifocal spectacles are shown in table 8f. Changing into multifocals post surgery increased falls risk significantly (OR=3.56, CI 1.34-9.43, P=0.011). The significance of these changes to and from multifocals and the vestibulo-ocular reflex gain will be discussed further in Chapter 9 along with the correction of ametropia between surgeries.

Table 8f: The falls rate of patients who changed either into or out of multifocal spectacles (bifocals and progressives) after cataract surgery compared to those that continued with multifocal wear or continued with their own distance vision spectacles or no spectacles.

Post-op spectacle wear	N	Falls rate
Into multifocals	30	30%
Continued with multifocals	62	23%
Discontinued multifocals	53	15%
Continued with single vision spectacles or without spectacles	133	17%

Levels of activity were similar before (86% of the participants were active) and after surgery (83% of the participants were active), with 19 participants becoming inactive when active before surgery, which was slightly greater than those becoming active after surgery when inactive before it (N=10). Of the 10 patients that where more active post surgery, four fell post surgery. This could be due to the increased risk of falling when walking outside the home, especially whilst adaptation to the new vision is occurring.

8.3. Dizziness Results

The median DHIsf score improved significantly following cataract surgery from 12 (IQR: 9-13) to 13 (IQR: 11-13), z=-13.38, p<0.001, indicating a reduction in dizziness post surgery. In the month before surgery, 52% of participants suffered with some form of handicap due to dizziness, whereas in the month after surgery this figure was reduced to 38% (χ^2 = 19.14 , p<0.001). This was similar for surgery on the first eye or both eyes, but the improvement was found not to be significant for the second eye surgery group (first eye surgery, 49% vs. 33%, p=0.01; second eye surgery 52% vs. 45%, p=0.68; surgery on both eyes, 58% vs. 35%, p<0.001).

8.4. Multivariate logistic regression models

The univariate and multivariate logistic regression models showing age, sex and significant, independent medical and visual/refractive factors are shown in Tables 8g-j for post-operative falls and dizziness respectively.

Age and sex were initially included in the post-operative falls model, but were not significant when pre-operative falls were included (age, p=0.47; sex, p=0.99) and their inclusion did not substantially affect the influence of the other variables that were included.

The multifactorial logistic model with post-operative falls as the outcome measure showed association with pre-operative falls and changes in spectacle type (into multifocal lens wear; Table 8h). This will be discussed further in Chapter 9.

Post-operative dizziness was strongly associated with falls (OR, 3.34, CI 1.78-6.26; $p<0.0001$), but pre-operative falls was a much stronger risk factor and acted as a proxy for multifactorial risk factors including age. Post-operative dizziness was retained in the final model (despite a p-value of 0.10) as it may be on the casual pathway between vision changes and falls.

Table 8j indicates that dizziness was present in patients who suffered from dizziness pre-surgery, with increasing age, with the number of medications and with greater changes in oblique astigmatism in the refractive correction. Post-operative dizziness was reduced for patients with large changes in habitual visual acuity. This will be discussed further in Chapter 9.

Table 8g: The univariate logistic regression containing independent risk factors for falls in the six months post-surgery (n=265). The odds ratios (OR) are shown with 95% confidence intervals (CI) and p-values.

	Non-adjusted (univariate)	
	OR (95% CI)	**p-value**
Age	1.06 (1.01-1.11)	0.020
Sex (females)	1.26 (0.69-2.29)	0.450
Walks outside	0.80 (0.38-1.68)	0.550
Number of chronic conditions	1.23 (1.00-1.51)	0.052
Number of medications	1.07 (0.98-1.18)	0.130
Arthritis	1.84 (0.96-3.52)	0.065
Sedatives	1.62 (0.71-3.71)	0.250
Best visual acuity post surgery	0.76 (0.13-4.48)	0.760
Change in anisometropia	0.85 (0.64-1.14)	0.280
Change in MSE	0.91 (0.71-1.16)	0.440
Change in J_0	0.71 (0.22-2.31)	0.570
Change in J_{45}	0.77 (0.22-2.71)	0.690
Pre-operative falls	8.74 (4.56-16.76)	<0.0001
Post-operative dizziness	3.34 (1.78-6.26)	<0.0001
Change into multifocal spectacles	2.52 (1.09-5.85)	0.030
Change from multifocal spectacles	1.60 (0.64-4.02)	0.320

Table 8h: Final multivariate logistic regression model containing independent risk factors for falls in the six months post-surgery (n=265). Adjusted (within the model) and the non-adjusted univariate odds ratios (OR) are shown with 95% confidence intervals (CI) and p-values. The likelihood ratio chi-squared value for the model was 49.2 ($p<0.0001$) with pseudo R^2=0.19

	Adjusted (multivariate)		Non-adjusted (univariate)	
	OR (95% CI)	**p-value**	**OR (95% CI)**	**p-value**
Pre-operative falls	7.28 (3.48-15.21)	<0.0001	8.74 (4.56-16.76)	<0.0001
Post-operative dizziness	1.83 (0.89-3.74)	0.1	3.34 (1.78-6.26)	<0.0001
Change into multifocal spectacles	3.56 (1.34-9.43)	0.011	2.52 (1.09-5.85)	0.03
Change from multifocal spectacles	1.81 (0.64-5.15)	0.27	1.60 (0.64-4.02)	0.32

Table 8i: The univariate logistic regression containing independent risk factors for dizziness in the six months post-surgery (n=262). The odds ratios (OR) are shown with 95% confidence intervals (CI) and p-values.

	Non-adjusted (univariate)	
	OR (95% CI)	**p-value**
Age	1.07 (1.03-1.11)	0.001
Sex (females)	1.86 (1.12-3.09)	0.016
Number of medications	1.20 (1.10-1.31)	<0.0001
Sedatives	2.98 (1.35-6.61)	0.007
Change in best eye habitual visual acuity	0.23 (0.06-0.09)	0.030
Change in MSE	1.06 (0.89-1.25)	0.520
Change in J_0	2.65 (1.13-6.24)	0.030
Change in J_{45}	7.87 (2.26-27.34)	0.001
Pre-operative dizziness	14.42 (7.48-27.79)	<0.0001
Change into multifocal spectacles	1.27 (0.57-2.83)	0.560
Change from multifocal spectacles	1.17 (0.52-2.64)	0.710

Table 8j: Final multivariate logistic regression model containing independent visual risk factors for dizziness in the month post-surgery (n=262). Adjusted (within the model) and non-adjusted univariate odds ratios (OR) are shown with 95% confidence intervals (CI) and p-values. The likelihood ratio chi-squared value for the model was 103.7 (p<0.0001) with pseudo R^2=0.32.

	Adjusted (multivariate)		**Non-adjusted (univariate)**	
	OR (95% CI)	**p-value**	**OR (95% CI)**	**p-value**
Pre-operative dizziness	12.08 (5.80-25.16)	<0.0001	14.42 (7.48-27.79)	<0.0001
Age	1.07 (1.01-1.13)	0.013	1.07 (1.03-1.11)	0.001
Sex (females)	1.90 (0.96-3.76)	0.065	1.86 (1.12-3.09)	0.016
Number of medications	1.17 (1.05-1.31)	0.005	1.20 (1.10-1.31)	<0.0001
Change in best eye habitual visual acuity	0.14 (0.02-0.83)	0.03	0.23 (0.06-0.09)	0.030
Change in best eye J_{45}	6.60 (1.36 - 32.07)	0.019	7.87 (2.26-27.34)	0.001

CHAPTER 9

DISCUSSION AND CONCLUSION

9.1. Discussion

This study found no change in overall falls rate after cataract surgery with pre and post-operative six-month rates of 23% and 20% respectively (equivalent to annual falls rate of 46% and 40%). These data are very similar to the pre and post-operative cataract surgery annual falls rate of 40-50% in similar studies (Harwood et al., 2005, Foss et al., 2006, McGwin et al., 2006). This lack of improvement in falls rate after cataract surgery is similar to previous reports (Harwood et al., 2005, Foss et al., 2006, McGwin et al., 2006) although Harwood and colleagues (2005) did report a small but a significant reduction in recurrent falls after first eye surgery. Two cohort studies that reported a large reduction in falls rate after first eye cataract surgery (Brannan et al., 2003, To et al., 2014) had much poorer pre-operative visual acuities (see section 5.1) of between 0.50-0.60 logMAR (Snellen 20/60-20/80) and included patients not representative of a typical Western cataract surgery population. In the study of Brannan and colleagues (2003), a very high pre-operative annual falls rate of 74% was found in a small sample of 84 patients. In To and colleagues (2014) a very low annual falls rate of 13% was reported in a much younger population (mean age 67 years).

From table 8e (see section 8.2), it is evident that the pre and post operative fallers (See section 8.2, Table 8e, Group 4) are very frail, taking a lot of medication and suffering with dizziness and arthritis. The falls are therefore likely to be occurring because they are frail, although the visual changes may be contributing to the many risks of falling they already have. The group of participants who fell post-operatively but didn't fall before their operation (See section 8.2, Table 8e, Group 3) are similar to Group 2 (See section 8.2, Table 8e, non-fallers) in terms of their medical data that were collected. However, participants in Group 3 may have found the extra vision risk factor adaptation post surgery harder to adapt to causing an increase in their dizziness, following Tinettis theory (Tinetti, Speechley, Ginter, 1988) of 'the more risk factors you have the more likely you are to fall' or some other risk factors in this group are present that were not collected in this study. Looking at table 8e (see section 8.2), the pre-surgery fallers (See section 8.2, Table 8e, Group 1) who do not fall after surgery are slightly frailer than the non-fallers group (See section 8.2, Table 8e, Group 2) and have a lot of polypharmacy and dizziness. However, the dizziness does improve post operatively; perhaps part of the reason why there are less falls post surgery in this group.

The multifactorial logistic model with post-operative falls as the outcome measure showed associations with pre-operative falls and changes in spectacle type (into multifocal lens wear; Table 8h). There were no significant associations with post-operative VA in the best or other eye, change in mean spherical equivalent refractive correction, change in astigmatic correction (J_0 or J_{45}), change in anisometropia, post-operative anisometropia, post-operative activity levels or change in activity levels (all $p>0.10$). However, the number of participants with large refractive changes in the operated eye was relatively small (over 4.00D: 33/283, 12%). Cumming and colleagues (2007) study found an increased falls rate with large change in spectacle correction (see section 5.3). Further studies with larger numbers of high refractive corrections before surgery may be useful.

Activity levels were similar before and after surgery, with 19 participants becoming inactive after surgery when active before surgery. This was typically due to ill health (e.g., arthritis, hip and knee problems). However, of the small number who greatly increased activity after surgery, all 10 had no falls before surgery, but four fell after surgery. It is possible that they increased their outdoor activity because of improvements in their visual confidence and put themselves at a greater risk of falling (Cumming et al., 2007). However, the number of participants in this subsample is small and a larger sample is required.

The association between falls and changes into or out of multifocal spectacles are shown in Table 8f and 8h. The falls rate in patients switching into multifocals is double (30%) that of those patients who discontinued multifocal wear (15%). This is in agreement with much of the literature, which suggests that multifocals are a risk factor for falls (Lord, Dayhew and Howland.,., 2002, Haran et al., 2010,). This is because all types of multifocal spectacles (bifocals and progressive addition) blur distance objects in the lower visual fields, increasing the risk of trip accidents and falls in older people, particularly when outside their homes and when walking up or down stairs (Lord, Dayhew and Howland., 2002). Progressive addition lenses are known to cause peripheral distortion and diplopia (double vision) and image jump has been reported at the reading segment edge in bifocals (Johnson et al., 2007).

One area particularly open to change is the correction of ametropia between surgeries. In those patients who had surgery in both eyes, 12 wore no correction for distance viewing between surgeries but used multifocals before first eye surgery and after second eye surgery (i.e. multifocal-none-multifocal). Of these, four (33%) fell post second eye surgery. For the 18 patients who retained multifocals throughout, three (17%) fell post second eye surgery. For 27 patients who gave up multifocals after first eye surgery (three wore distance vision spectacles, the remainder wore none) only two (7%) fell post second eye surgery (two patients retained multifocals after first eye surgery, but removed the lens in front of the operated eye, then wore no lenses for distance viewing after second eye surgery and one fell). The first group (multifocal-none-multifocal) would have needed to adapt to not wearing multifocals after first eye surgery and then re-adapt to wearing them after second eye surgery. This would therefore include two adaptations to the vestibulo-ocular reflex gain, which is variable in multifocals (Michaelides and Schutt., 2014). However, the number of patients in this comparison is small and this needs further study.

Self-reported dizziness was greater in females and patients with multiple medications (table 8j, section 8.4) and this is similar to earlier findings (Tinetti, Williams and Gill., 2000, Gassmann, Rupprecht and Group IZGS., 2009).

The reported prevalence of dizziness depends on the definition used and the population studied (Yardley et al., 1998, Tinetti, Williams and Gill., 2000, Stevens et al., 2008). The prevalence of dizziness in Stevens and colleagues (2008) study was reported low at 11% in a large population-based UK study of approximately 3,000 elderly adults added 65 years and over. The definition of dizziness used in this study was “dizziness when you are walking on a level surface”. Wider definitions of dizziness (i.e. not just when walking) provide higher figures. In this study the dizziness prevalence figures are high at 52% pre-operative and 38% post-operative. This is very likely due to the wide definition used in this study, anybody indicating dizziness to any one of the 13 questions of the DHIsf were classified as dizzy.

Studies have shown a strong link between dizziness and reduced quality of life (Neuhauser et al., 2008, Gopinath et al., 2009). Cataract guidelines state that patients with cataract should have sufficient cataract to account for their visual symptoms and that the cataract should affect the patient's lifestyle (Lundstrom et al., 2012). Although this is thought to mean everyday tasks, such as driving, seeing faces and reading, i.e. tasks that are reliant on vision. This study suggests that dizziness should also be considered.

In this study, poorer visual acuity (i.e. higher logMAR score) was found to be an independent risk factor for post-operative dizziness (OR 0.14, Table 8j). The improvement in dizziness, due to cataract surgery, is probably as a result of the improvements in visual acuity and is likely to be linked with improvements in postural stability (Schwartz et al., 2005, Willis et al., 2013).

This study also found, greater changes in J_{45}, the vector representing oblique astigmatism, which was also a risk factor for post-operative dizziness (OR 6.60, Table 8j). This finding was not surprising given that oblique astigmatism is known to produce the greatest problems of distortion (Johnson et al., 2013).

The strong link between the post-operative falls rate and dizziness symptoms found in this study was expected and has been suggested by other studies (Colledge et al., 1996, Stevens et al., 2008). This suggests that those visual and refractive factors influencing dizziness may also indirectly influence falls rates. In this way, falls risk may be reduced due to the reduction in dizziness caused by improved visual acuities post cataract surgery and may be increased by changes in oblique astigmatic refractive correction post cataract surgery.

9.2. Study limitation

This study was limited in several ways. It is well known that the ageing process can affect memory and as our participants were all over the age of 65, memory was a limiting factor. The falls data were self-reported recall from the previous 6 months and accurate retrospective assessments of falls are difficult due to poor memory recall of older patients (Cummings, Nevitt and Kidd., 1988). Due to this, less falls may have been reported than expected. In this study, a definition of what constitutes a fall was given in layperson's terms, however each participant's interpretation of the definition may have varied (Lamb et al., 2005).

In this study it was not possible to send out a Mini Mental State Examination questionnaire to every participant because of the additional burden it would have placed on the participants. It was considered unethical to include as the burden would far outweigh the benefit obtained from such information being collected. The Mini Mental State Examination questionnaire has not been validated for completion by post or to be filled in by self-report.

In this study attempts were made to improve the data by collecting prospective data using falls diaries, but were limited to a median period of 2 months due to the short time period between initial referral and cataract surgery. To allow a fair comparison of falls data pre and post-operatively, post-op falls using falls diaries were only collected for the same amount of time (2 months median). The waiting lists for cataract surgeries in the past were a lot longer and collecting prospective data for a greater length of time was possible.

Monocular visual acuity and spectacle refraction data were taken from clinical records. Some of these data were taken by nurses and some from the participants' optometrist. This may have caused slight discrepancies, as the same optometrist/nurse did not take all the measurements used in this study. It was also not possible to extract other visual data which would have allowed us to assess other visual aspects that may have been associated with falls and dizziness such as, binocular visual acuity, contrast sensitivity, visual field and stereoacuity data. These measurements were not available in the clinical records, as they are not routinely measured on these patients.

Outdoor activity was taken from a simple question about outdoor activity and preference would be for a more detailed questionnaire assessment and/or perhaps pedometer measurements.

Finally, the study has highlighted several areas that would benefit from data collection from a larger sample of pre and post-operative cataract surgery patients and these include patients with large refractive changes and different multifocal wearing patterns of patients undergoing surgery on both eyes.

9.3. Future research

Further data are needed from a larger sample of participants with high refractive corrections before surgery. Cumming and colleagues (2007) found an increased falls rate with large change in spectacle correction (see section 5.3). Therefore further research in this area would be beneficial to see whether or not these findings are reliable.

The design of the study would be very similar to the present one. The falls data would be collected retrospectively before and after the cataract surgeries. This is in light of the decrease in waiting times for cataract surgery, making it difficult to collect a sufficient amount of prospective data over a longer time period.

The recruitment and the collection of data should take place in person following the initial consultation with the ophthalmologist. If the patient is deemed likely to benefit from the cataract surgery by the ophthalmologists, they will be placed on the waiting list. A study team member should ask the patient if they are willing to take part in the study. Those patients that consent to the study and fit the criteria with large refractive corrections will be easily accessible immediately after the consultant's examination to undergo further visual tests. Once the patients are identified, the same member of the study team should take the measurements to ensure the results are consistent rather than being taken from medical records. All the measurements should be taken in the same hospital and the examination room. Additional tests that are not routinely taken and hence are missing from the medical record, but would greatly benefit this future study include binocular visual acuity measurements (ETDRS charts or similar), Pelli-Robson contrast sensitivity chart and stereopsis measurements using the TNO test. It would be beneficial to find a large sample of patients that are having cataract surgery on both eyes. It would also be very valuable to obtain the habitual refraction and type of spectacles worn before the surgeries; post first and post second eye surgery. The additional tests can be carried out at the same time instead of relying on medical records which may not be as accurate. The rest of the data including information about the participants' home environment and factors known to be related to falls at home, such as stairs and co-residence can be obtained using the general questionnaire (See Appendix A.7). Information about the participants' activity levels can also obtained from the general questionnaire. Information regarding general health status can be obtained using the participants' medical records.

9.4. Conclusion

In summary, this study found no improvement in falls rate with routine cataract surgery. This is probably due to the relatively good pre-operative visual acuities and possibly due to too many patients switching to multifocal spectacle wear post-surgery. This suggests that to maximise the potential for cataract surgery to improve falls rates, patients should be appropriately warned of the potential adaptation problems after surgery, particularly if they have switched to multifocal wear. For those patients undergoing cataract surgeries in both eyes and are multifocal wearers, these patients should consider wearing updated multifocals rather than going without spectacles, if the intention is to continue multifocal wear post second eye surgery.

In this study, dizziness was reduced by cataract surgery and this was linked with improvements in best eye habitual visual acuity, but increased by changes in oblique astigmatic correction. This needs to be investigated further to determine whether dizziness should be a consideration in the decision of whether or not to perform cataract surgery.

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APPENDIX A: PARTICIPANTS SHEETS

APPENDIX A.1: INVITATION LETTER

Bradford Teaching Hospitals NHS
NHS Foundation Trust

Dear

Included with this covering letter is an information leaflet about a research study concerning cataract, dizziness and falls that Mr Norman Litvin (Ophthalmology consultant, Bradford Royal Infirmary) and I are conducting with Professor David Elliott of the University of Bradford. Details about the research are provided in the information letter. Your participation in the study would be greatly valued and will contribute to the improvement of Bradford Hospital's provision of eye care. However, you are not under any obligation to take part in this study and if you decide that you do not wish to take part, this will not affect the standard of care you receive, and you can withdraw from the study at any time.

If you are willing to participate in the study please complete the enclosed consent form, questionnaire, falls diary and dizziness questionnaire and return them to me in the envelope provided.

Thank you for your consideration.

Yours sincerely,

Clare Green BSc MCOptom DipTp(AS) DipTp(SP), DipTp(IP)

APPENDIX A.2: PARTICPANT INFORMATION SHEET

Study Title: Dizziness and Falls after Cataract Surgery

The following information is provided as required by the NHS National Research Ethics Service (NRES).

Who are we?

Clare Green and Norman Litvin are consultants in Optometry and Ophthalmology at the Bradford Royal Infirmary. David Elliott is a professor and researcher from the School of Optometry at the University of Bradford. Elvira Supuk is a PhD student from the School of Optometry at the University of Bradford. We are researching whether dizziness and falls change after cataract surgery.

What is the purpose of the study?

We know that poor vision causes people to fall more, so that correcting poor vision by cataract surgery should help to reduce falls. However, several studies that have been performed to date have not found the expected improvements and we want to find out why.

Why is the study important?

Dizziness and falls can cause major problems for older people and if cataract surgery (under certain conditions) can help to reduce falls and dizziness this would be a great help to many people.

Why have I been chosen?

Because you have recently been scheduled for cataract surgery in the Hospital Eye Service at Bradford or Airedale.

What will happen if I agree to take part?

We will ask you to complete a simple monthly falls diary (it should take about 2-3 minutes) three times before surgery and three times after surgery and a simple questionnaire about dizziness (it should take about 7 minutes) once before surgery and once after. We are therefore asking for about half an hour of your time in total. These will be posted to you at the appropriate times and we would ask that you complete them as soon as possible once received and return them in the postage paid envelopes that we will provide. We will also ask you some questions about your age, general health and medications, whether you have a history of falling and record the power of your spectacles and how well you can see in them to see if they help us to find out why some people have fewer falls and less dizziness after cataract surgery and why some people have more falls and dizziness. It is therefore important you bring your spectacles with you to the clinic.

<u>What happens after this?</u>

Your medical data will not be stored with your name and address but with an identification code. Personal information that is required for contacting you will also be stored separately from your medical data under password protection. Information from your records will be stored on University computers that are password protected. Your personal details will be linked to questionnaire responses via codes. These codes will be stored on a University computer and will be password protected. The passwords to these documents will not be written down and will only be known by Professor David Elliott (Chief Investigator) and Elvira Supuk (Research Assistant). The questionnaire responses from all patients will be gathered together and analysed to see how whether any improvements to cataract surgery can be made.

<u>Is there any risk of harm to myself?</u>

No, there will be no extra clinical procedures performed on you by the researchers. All the information we need will be taken from the questionnaires you complete. The questionnaire that we ask you to complete is commonly used by doctors and researchers to measure the effects of dizziness. If you have a concern about any aspect of this study please let us know and we will do our best to answer your questions. If you remain unhappy and wish to complain formally, you can do this through the NHS Complaints Procedure. Details can be obtained from the hospital.

<u>Who is funding the study?</u>

The study is funded by Dunhill Medical Trust (Ref No: DMT SA 14/0711)

Who has reviewed the study?

All research in the NHS is looked at by independent group of people, called a Research Ethic Committee to protect your safety, rights, wellbeing and dignity. This study has been reviewed and given favourable opinion. (REC Reference Number: 12/EE/0038)

Who is providing indemnity insurance?

The University of Bradford indemnity policy (NHE-03CA01-0023).

Why should I be involved?

You are under no obligation to take part in this study. However, your participation will be greatly valued and will contribute to the improvement of Bradford Hospital's provision of eye care. If you wish to take part in the study please complete the consent form as soon as possible and return the form to Clare Green in the pre paid envelope attached. If you decide that you do not wish to take part, this will not affect the standard of care you receive, and you can withdraw from the study at any time by informing one of the members of the research team.

The results of this study will be used for research purposes. If published, all data will remain anonymous. If you would like to be notified of where the research is published, please let a member of the research team know. Thank you for taking time to read this information sheet.

FURTHER INFORMATION AVAILABLE FROM MEMBERS OF THE RESEARCH TEAM:

Professor David B Elliott, School of Optometry, University of Bradford: tel 01274 235224.

Ms Clare Green, Optometrist Consultant; Mr Norman Litvin, Consultant Ophthalmologist; Bradford Royal Infirmary.

APPENDIX A.3: CONSENT FORM

Study Title: Dizziness and Falls after Cataract Surgery

Please write your initials in all boxes:

I have read and understood the Patient Information Sheet dated 10/12/12, version 4. ☐

I have had the opportunity to ask questions and discuss the research study. ☐

I give permission for individuals from the study team, from regulatory authorities or from the NHS Trust to access my medical records to obtain relevant information required for the research. ☐

I give permission for the study team to contact my optician to obtain any further information required for the research. ☐

I understand that I am free to withdraw from this study at any time without affecting the standard of care I receive. ☐

I agree to take part in this research study. ☐

Name(CAPITALS)..

Signature......................................Date..............

POST OPERATIVE FALLS DIARY: MONTH ONE

TODAY'S DATE.........................

What date did you have your cataract surgery?.................................

Have you updated your glasses since having your cataract surgery? ☐ No ☐ Yes

If yes, when did you get your new glasses?......................................

During this month, have you had any falls including a slip or trip in which you lost your balance and landed on the floor or ground or lower level?

☐ No. I had no falls this month.

☐ Yes. How many falls did you experience?.................................

Please describe these falls, if any:

Fall 1:

Date and time:……………………….....Location:…………………

Circumstances:……………………………………………………

Did you suffer any injuries as a result of the accident?

☐ No ☐ Yes

If yes, please tick if you suffered any of the following injuries?

☐ Bruise ☐ graze/cut ☐ break/fracture

Other (please specify):……………………………………….........

Did you require any medical treatment?..

What glasses were you wearing at the time of the fall (if any)?

Please tick appropriate box.

☐ Varifocals ☐ Bifocals ☐ Distance ☐ Reading ☐ None

Fall 2:

Date and time:…………………………......Location:………………

Circumstances:……………………………………………………

Did you suffer any injuries as a result of the accident?
 No Yes

If yes, please tick if you suffered any of the following injuries?
 Bruise graze/cut break/fracture
Other (please specify):……………………………………….......

Did you require any medical treatment?.......................................

What glasses were you wearing at the time of the fall (if any)?
Please tick appropriate box.
 Varifocals Bifocals Distance Reading None

Please attach another page to describe any additional falls.

APPENDIX A.5: DIZZINESS HANDICAP INVENTORY QUESTIONNAIRE

The short form of the Dizziness Handicap Inventory

In the following questions, "**your problem***" means any problems you may have with **dizziness**, **vertigo**, **unsteadiness** or **poor balance.**

Please answer regarding any problems over the last month.

Please tick or ring the most appropriate response.

Does looking up increase your problem*?	Yes	No
Because of your problem*, do you restrict your travel?	Yes	No
Because of your problem*, do you have difficulty getting in and out of bed?	Yes	No
Because of your problem*, do you have difficulty reading?	Yes	No
Do quick eye movements increase your problem*?	Yes	No
Because of your problem*, do you avoid heights?	Yes	No
Does turning over in bed increase your problem*?	Yes	No
Because of your problem*, is it difficult for you to go for a walk by yourself?	Yes	No
Does walking along pavements increase your problem*?	Yes	No
Because of your problem*, is it difficult for you to walk around your house in the dark?	Yes	No
Because of your problem*, are you afraid to stay home alone?	Yes	No
Because of your problem*, are you depressed?	Yes	No
Does bending over increase your problem*?	Yes	No

Spectacle questionnaire

It is OK to write additional information to help answer the questions.

1. Since you had your first cataract operation, have you seen your optician for an eye test? Please tick the appropriate box.
   - ☐ Yes
   - ☐ No
2. Since you had your first cataract operation, are you still wearing your glasses at the same times as you did before? Please tick appropriate box.
   - ☐ Yes
   - ☐ No
   - ☐ Not wearing glasses at all
3. If you are wearing glasses but in a different way, please tell us how. Tick ALL boxes that apply:
   - ☐ I have got new glasses from my optician since the operation
   - ☐ I have got one new lens in my glasses since the operation
   - ☐ One of the lenses has been removed from my glasses
   - ☐ I am wearing an eye patch during the day
   - ☐ I am wearing an old pair of glasses
   - ☐ I am wearing some ready-made reading glasses bought since the operation
4. When do you wear your glasses? Please tick appropriate box.
   - ☐ Near vision only
   - ☐ Distance vision only
   - ☐ All/most of the time
   - ☐ No glasses worn
5. Do you wear your glasses when walking up and down stairs?
   - ☐ Yes
   - ☐ No
   - ☐ Not Applicable
   - ☐

Version 2, Created date 10th July 2012

General Questionnaire

1. Does your home have stairs? Please tick the appropriate box.
   - ☐ Yes
   - ☐ No

2. Do you live alone? Please tick appropriate box.
   - ☐ Yes
   - ☐ No

3. How many times have you fallen in the last 6 months? Please tick the appropriate box.
   (A fall is defined here as 'a slip or trip in which you lost your balance and landed on the floor or ground or lower level').
   - ☐ None
   - ☐ 1-2
   - ☐ 3-4
   - ☐ 5-6
   - ☐ More than 6

4. How often do you walk outside for half an hour? Please tick the appropriate box.
   - ☐ Everyday
   - ☐ One to two times a week
   - ☐ One to two times a month
   - ☐ Seldom
   - ☐ Never

5. What type of glasses do you wear? Please tick appropriate box.
   - ☐ Varifocals
   - ☐ Bifocals
   - ☐ Distance vision
   - ☐ Near/Reading vision
   - ☐ Distance and near vision
   - ☐ None

6. When do you wear your glasses? Please tick appropriate box.
   - ☐ Near vision only
   - ☐ Distance vision only
   - ☐ All/most of the time
   - ☐ No glasses worn

7. Do you wear your glasses when walking up and down stairs?
   - ☐ Yes
   - ☐ No
   - ☐ Not Applicable

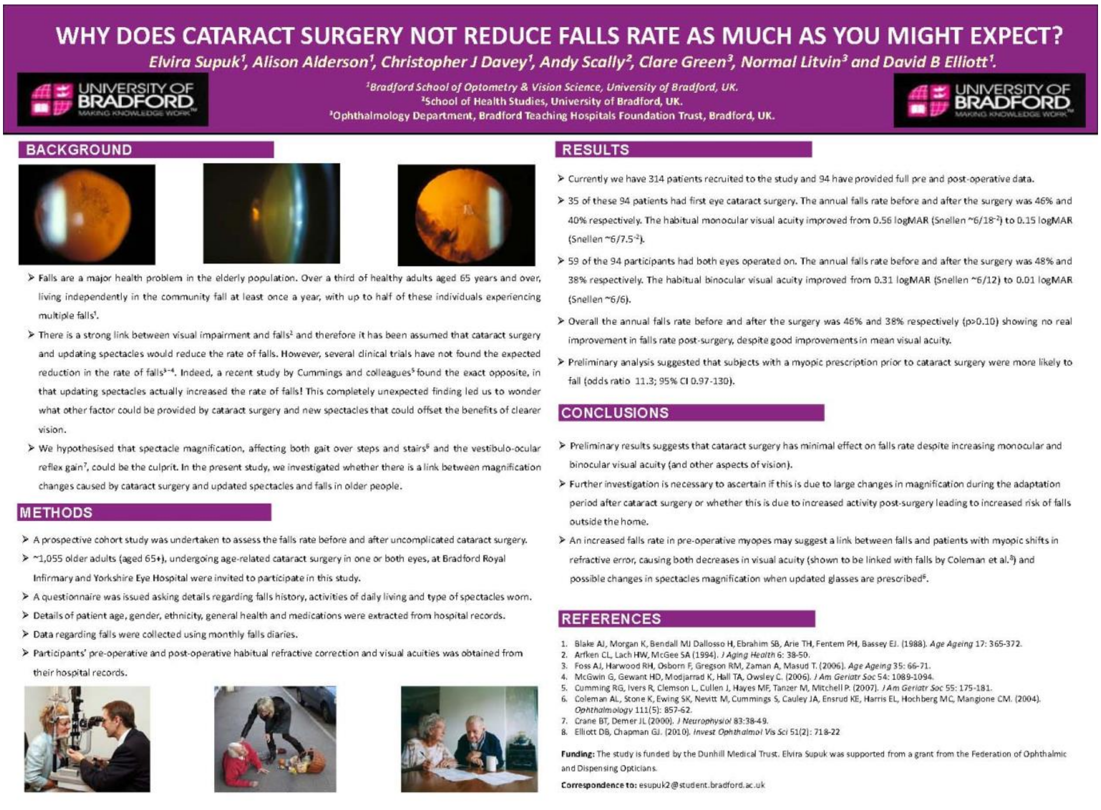
8. Are you having your first eye cataract removed or your second eye cataract? Please tick appropriate box
   - ☐ First Eye
   - ☐ Second Eye

9. If you are having your second eye cataract removed did you get new glasses after you had your first eye cataract removed?
   - ☐ Yes
   - ☐ No

APPENDIX B: DISSEMINATION OF RESEARCH

APPENDIX B.1: Poster Presentation 1

Supuk E, Alderson A, Davey CJ, Scally AJ, Green C, Litvin N, Elliott DB. (2014): Why does cataract surgery not reduce falls rate as much as you would expect? Optometry Tomorrow, York.

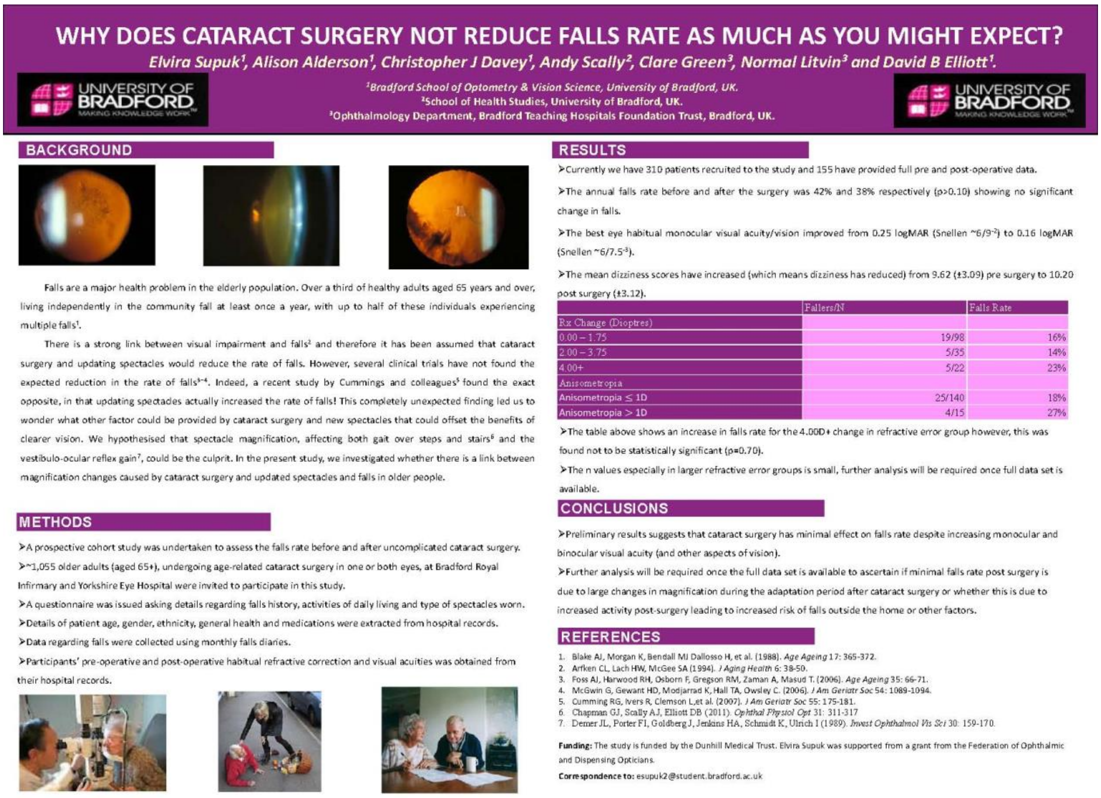


APPENDIX B.2: Poster Presentation 2

Supuk E, Alderson A, Davey CJ, Scally AJ, Green C, Litvin N, Elliott DB. (2013): Why does cataract surgery not reduce falls rate as much as you would expect? British Congress of Optometry and Vision Science, Glasgow, 2013.

Abstract published in Ophthalmic & Physiological Optics:

Abstracts: British Congress of Optometry and Vision Science, Glasgow, 2013. *Ophthalmic & Physiological Optics (2014), 34, 104-122*



APPENDIX B.3: Published Paper: Ophthalmic & Physiological Optics (2015)

OPO OPHTHALMIC & PHYSIOLOGICAL OPTICS
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Dizziness, but not falls rate, improves after routine cataract surgery: the role of refractive and spectacle changes

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Keywords: astigmatism, cataract surgery, dizziness, falls, multifocals, refractive correction

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Abstract

Purpose: To determine whether dizziness and falls rates change due to routine cataract surgery and to determine the influence of spectacle type and refractive factors.

Methods: Self-reported dizziness and falls were determined in 287 patients (mean age of 76.5 ± 6.3 years, 55% females) before and after routine cataract surgery for the first (81, 28%), second (109, 38%) and both eyes (97, 34%). Dizziness was determined using the short-form of the Dizziness Handicap Inventory. Six-month falls rates were determined using self-reported retrospective data.

Results: The number of patients with dizziness reduced significantly after cataract surgery (52% vs 38%; $\chi^2 = 19.14$, $p < 0.001$), but the reduction in the number of patients who fell in the 6-months post surgery was not significant (23% vs 20%; $\chi^2 = 0.87$, $p = 0.35$). Dizziness improved after first eye surgery (49% vs 33%, $p = 0.01$) and surgery on both eyes (58% vs 35%, $p < 0.001$), but not after second eye surgery (52% vs 45%, $p = 0.68$). Multivariate logistic regression analyses found significant links between post-operative falls and change in spectacle type (increased risk if switched into multifocal spectacles). Post-operative dizziness was associated with changes in best eye visual acuity and changes in oblique astigmatic correction.

Conclusions: Dizziness is significantly reduced by first (or both) eye cataract surgery and this is linked with improvements in best eye visual acuity, although changes in oblique astigmatic correction increased dizziness. The lack of improvement in falls rate may be associated with switching into multifocal spectacle wear after surgery.

Introduction

Falls are the major cause of death and non-fatal injuries in the elderly.[1,2] They are also relatively common, with at least a third of community-dwelling, healthy adults aged 65 years and over falling once a year or more.[1,2] Falls in older adults are not random, chance events or 'accidents', but typically multifactorial and linked to geriatric syndromes[3,4] and most epidemiological studies have shown that visual impairment is a significant and independent risk factor for falls with an average odds ratio of 2.0.[5] In addition, clinical audit studies have reported that many older adults who attended emergency clinics because of a fall or who had undergone hip fracture surgery had visual impairment, of which about one-third was correctable by cataract surgery.[6,7]

These studies suggest that providing cataract surgery to older people at risk of falling would lead to reductions in falls rates. However, although two open-design intervention studies of cataract surgery found significant improvements in falls rates after cataract surgery,[8,9] cohort studies and randomised controlled trials provide much more equivocal results.[10-12] Indeed, Deandrea *et al.*[13] concluded that there was no evidence that cataract surgery reduced falls rate after combining the data from the two randomised controlled trial studies[11,12] in a meta-analysis. The results from large-scale assessments of the effect of cataract surgery on injurious falls have also been equivocal.[14,15]

Self-reported dizziness was also included as a principal outcome measure in this study. Dizziness is highly prevalent in the older population,[16] is linked to falls[13,17,18] and may be increased with poor vision.[19-21]

We hypothesised that there are some factors associated with cataract surgery that lead to a relatively greater risk of falling (and increased dizziness) which may in some circumstances offset the reduction in falls risk (and dizziness) due to improvements in visual function. These could include the following:

- Increased anisometropia after first eye surgery.[14,22]
- Adaptation problems to large changes in refractive correction.[23] These include spectacle magnification and astigmatic distortion changes increasing trip risk on steps and stairs[24,25] and requiring adaptation of the vestibulo-ocular reflex gain. Patients can complain of their visual world appearing to 'swim' until adaptation occurs.[24]
- Switching to multifocal spectacles.[26-28]
- Increased confidence leading to greater outdoor activities and increased fall risk.[23]

These factors were assessed and multivariate logistic regression analyses were used to determine whether they had a significant independent effect on post-operative falls rates and self-reported dizziness.

As far as we are aware, this is the first study to attempt to determine why cataract surgery does not improve falls rate as much as expected and the first to evaluate the effect of cataract surgery on dizziness.

Methods

Study design and participants

Participants were recruited for this cohort study from the cataract waiting lists of two hospitals in the UK, Bradford Royal Infirmary and Yorkshire Eye Hospital, between July 1, 2012 and July 31, 2013. All patients 65 years and older who were listed for routine phacoemulsification with a monofocal IOL during this period were sent details about the study (~1240). The study was approved by the East of England NHS Research Ethics Committee and adhered to the tenants of the Declaration of Helsinki. All participants gave written, informed consent to participate in the study and for the research team to access their hospital medical records and contact their optometrist for relevant information regarding their refractive correction.

Procedures

Close to the surgery date participants were sent a list of questions requesting information regarding outdoor activity levels (everyday, 1–2 times per week, 1–2 times per month, seldom or never) and type of spectacles worn for walking (none, single vision, progressive addition or bifocals). Data regarding the participants' age, sex, general health status, the number and type of prescribed medications and their pre- and post-operative habitual refractive correction and habitual visual acuity (i.e. with the spectacles they were usually wearing for distance tasks) were obtained from the participants' medical records. Any missing data were followed up by telephone calls to the participant and/or their optometrist.

Dizziness assessment

The most commonly used and accepted questionnaire to quantify the impact of dizziness on everyday life is the Dizziness Handicap Inventory (DHI) yet despite this its structural validity is not established.[29] In this study, participants were sent a copy of the short form of the dizziness handicap inventory (DHIsf), which has been validated using Rasch analysis.[30] The DHIsf comprises 13 questions, each with a yes/no answer and a participant with a score of 13 has no handicap from dizziness whereas a score of zero would indicate extreme handicap. Participants were asked to complete the DHIsf with regards to any dizziness they had suffered in the previous month. Patients were sent the DHIsf approximately 1 month prior to surgery and 1 month post surgery (after the 2nd eye for those that had surgery on both eyes).

Falls assessment

Given the short waiting times for NHS cataract surgery at the time, patients could only be recruited to the study a relatively short period prior to their surgery (median 25 days, range 14–40 days). To obtain an assessment of pre-operative self-reported falls over a larger period, we retrospectively asked if patients had fallen within the last 6 months. A fall was defined as 'an unexpected event in which the participants come to rest on the ground, floor, or lower level'.[31] All patients that reported falling were asked to give further information including the number of falls that had occurred and whether they were wearing spectacles at the time of each fall. In an attempt to improve the accuracy of the falls data, participants were also sent falls diaries in the period after consenting to participate in the study and before surgery (median 25 days, range 14–40 days).

Self-reported 6-month falls data were collected in the same way post-operatively: participants were sent monthly falls diaries for completion for 1–2 months (equivalent to the number of completions pre-surgery) and after

6 months, they were sent the same questionnaire requesting information regarding the occurrence of falls in the previous 6 months. The response to the 6-month retrospective falls question was checked against the falls diary information and any inconsistencies were investigated (although the falls diary information was only a useful check for the situation of a reported fall in the falls diary versus no fall in the 6-month retrospective information and this did not occur). The data reported are the self-reported 6-month falls data.

Statistical analysis

A target sample size of 280 was calculated using Peduzzi and colleagues[32] formula of $N = 10$ k/p, where k is the number of covariates accounted for and p is the likely proportion of positive cases (falls rate in this study and taken to be 25%). Data analysis was carried out using STATA, version 13.1. For analysis all Snellen visual acuity (VA) measurements were converted to logMAR. The participant's habitual refractive correction (i.e. their spectacles worn when walking) was converted into power vector format to enable comparison of pre and post-operative data.[33] As we were interested in the overall change in both spherical correction and astigmatism, but not the direction of the change (i.e. we assumed that in terms of their effect on dizziness and falls, a 6.00DS reduction in hyperopic correction would have similar effects to a 6.00DS myopic reduction and a 1.00DC swing towards against-the-rule astigmatism would be similar to a 1.00DC swing towards with-the-rule astigmatism), the absolute value of the changes due to surgery in mean sphere equivalent and the vector values of astigmatism J_0 and J_{45} were used in the analyses. Changes in refractive correction from second eye surgery were used in the analyses from patients who underwent surgery in both eyes as falls were assessed after second eye surgery for those patients.

Normality of continuous data was determined using the Kolmogorov-Smirnov test. Age, dizziness, number of medications, number of chronic conditions and vision data were not normally distributed and therefore they are described in terms of medians and inter-quartile ranges (IQR). Differences between demographic data for included and excluded participants were analysed using the Mann–Whitney U test for continuous data and the chi-square test for categorical data.

A comparison of the DHIsf score before and after cataract surgery was carried out using the Wilcoxon signed rank test for dependent samples. As the dizziness score data were highly skewed, participants were dichotomised into those who scored 13 on the DHIsf as having no handicap from dizziness, and those who scored <13 on the DHIsf as having some level of handicap from dizziness. Changes in prevalence of dizziness and falls pre and post-surgery were analysed using McNemar's test. As the activity levels data were skewed, participants were dichotomised into those who were active (n = 248; outdoor activity at least 1–2 times per week) and those who were inactive (n = 39; outdoor activity 1–2 times per month or less). Visual acuity and refractive correction data were assigned to the 'best' and 'worst' eye (rather than the operated and non-operated eye) as binocular visual function is typically related to vision in the best eye.[34] Multivariate logistic regression models for post-operative self-reported falls and dizziness (both dichotomous, falls or not, dizziness or not) were developed that included age and sex and any significant medical factor. Any visual and/or refractive factor that showed a univariate logistic regression p-value of <0.10 were then entered into the model to produce final models of independent risk factors for both post-operative self-reported dizziness and falls.

Results

Three hundred and sixty-four patients indicated an interest in participating. Seventy-seven were excluded from the study and/or analysis with 287 (79%) completing the study. This is similar to the recruitment in the earlier UK cataract surgery studies.[11,12] A breakdown of the reasons for exclusion is shown in *Figure* 1. There was no significant difference in age (U = 10245, $p = 0.33$) or sex ($\chi^2 = 0.11$, $p = 0.80$) between those included (age 77 years, 55% female) and those excluded (age 74 years, 53% female) from the study. Of the 287 patients completing the study (mean age 76.5 ± 6.3 years; 55% females; 93% Caucasian), 81 (28%) had routine cataract surgery in the first eye, 109 (38%) in the second eye and 97 (34%) had surgery in both eyes. The latter group were those patients in whom there was <6 months between first and second eye surgery (median 57 days, IQR 43-81 days) so that we were unable to collect 6-month falls data between surgeries. For these participants, a post-operative falls rate was collected for the 6-month period after their 2nd eye surgery.

Median (and IQR) refractive correction and habitual VA data before and after cataract surgery for the operated and non-operated eye are provided in Table 1. The number of patients wearing spectacles for distance viewing was reduced after surgery (from 196/287, 68% to 147/285, 52%; Fishers exact test, $p < 0.0001$).

The self-reported 6-month falls rate remained similar before and after cataract surgery ($\chi^2 = 0.87, p = 0.35$), with 66 of 287 (23%) of the participants reported falling in the 6 months prior to surgery compared to 56 of 283 (20%) that reported falling in the same period after surgery. Levels of activity were similar before (86% active) and after surgery (83% active).

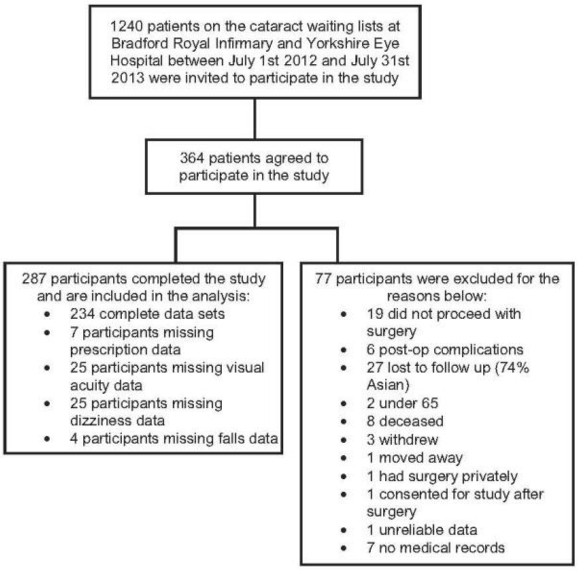

Figure 1. A breakdown of the reasons for participant exclusion.

Table 1. Median (inter-quartile range) pre and post-operative absolute values of refractive correction (N = 280) and habitual visual acuity (N=262) before and after cataract surgery in the operated and non-operated eye

	Operated Eye		Non-Operated Eye (1st eye surgery)		Non-Operated Eye (2nd eye surgery)	
	Pre-Op	Post-op	Pre-Op	Post-Op	Pre-Op	Post-Op
MSE (D)	1.25 (0.00 2.88)	0.0 (0.00 0.50)	1.38 (0.00 2.25)	0.00 (0.00 1.34)	0.00 (0.00 0.50)	0.00 (0.00 0.38)
J_0 (D)	0.13 (0.00 0.48)	0.00 (0.00 0.31)	0.13 (0.00 0.48)	0.00 (0.00 0.28)	0.00 (0.00 0.19)	0.00 (0.00 0.39)
J_{45} (D)	0.07 (0.00 0.27)	0.00 (0.00 0.13)	0.04 (0.00 0.19)	0.00 (0.00 0.08)	0.00 (0.00 0.19)	0.00 (0.00 0.16)
Habitual VA	0.30 (0.20 0.40)	0.10 (0.00 0.24)	0.20 (0.10 0.28)	0.24 (0.10 0.80)	0.20 (0.00 0.26)	0.10 (0.00 0.24)

Changes in the non-operated eye are typically due to changes in spectacle wear.
MSE, mean spherical equivalent in dioptres; J_0 and J_{45}, Vector values of astigmatism in the ordinal and oblique meridians respectively; Habitual VA, monocular visual acuity (in logMAR) measured with the patients' own distance spectacles if worn.

The median DHIsf score improved significantly following cataract surgery from 12 (IQR: 9–13) to 13 (IQR: 11–13), $z = -13.38$, $p < 0.001$, indicating a reduction in dizziness. In the month prior to surgery 52% of participants suffered some form of handicap due to dizziness, whereas in the month after surgery this figure was reduced to 38% ($\chi^2 = 19.14$, $p < 0.001$). This was similar for surgery on the first eye or both eyes, but the improvement was not significant for second eye surgery (first eye surgery, 49% vs 33%, $p = 0.01$; second eye surgery 52% vs 45%, $p = 0.68$; surgery on both eyes, 58% vs 35%, $p < 0.001$).

The most parsimonious multivariate logistic regression models showing significant, independent medical and visual/refractive factors are shown in Tables 2 and 3 for post-operative falls and dizziness respectively. Age and sex were initially included in the post-operative falls model, but were not significant when pre-operative falls were included (age, $p = 0.47$; sex, $p = 0.99$) and their inclusion

Table 2. Final multivariate logistic regression model containing independent risk factors for falls in the 6 months post-surgery ($n = 265$)

	Adjusted (multivariate)		Non-adjusted (univariate)*	
	OR (95% CI)	p-value	OR (95% CI)	*p*-value
Pre-operative falls	7.28 (3.48 15.21)	<0.0001	8.74 (4.56 16.76)	<0.0001
Post-operative dizziness	1.83 (0.89 3.74)	0.10	3.34 (1.78 6.26)	<0.0001
Change into multifocal spectacles	3.56 (1.34 9.43)	0.011	2.52 (1.09 5.85)	0.03
Change from multifocal spectacles	1.81 (0.64 5.15)	0.27	1.60 (0.64 4.02)	0.32

Adjusted (within the model) and non-adjusted univariate odds ratios (OR) are shown with 95% confidence intervals (CI) and *p*-values. The likelihood ratio chi-squared value for the model was 49.2 ($p < 0.0001$) with pseudo $R^2 = 0.19$.

*Other univariate odds ratios (*p*-value) for factors not included in the final multivariate model included age 1.06 (0.017), sex 1.26 (0.45), walks outside 0.80 (0.55), number of chronic conditions 1.23 (0.052), number of medications 1.07 (0.13), arthritis 1.84 (0.065), sedative use 1.62 (0.25), best visual acuity post surgery 0.76 (0.76), change in best visual acuity 0.55 (0.45), change in anisometropia 0.85 (0.28), change in mean sphere equivalent 0.91 (0.44), change in J_0 0.71 (0.57), change in J_{45} 0.77 (0.69).

Table 3. Final multivariate logistic regression model containing independent visual risk factors for dizziness in the month post-surgery ($n = 262$)

	Adjusted (multivariate)		Non-adjusted (Univariate)*	
	OR (95% CI)	*p*-value	OR (95% CI)	*p*-value
Pre-operative dizziness	12.08 (5.80 25.16)	<0.0001	14.42 (7.48 27.79)	<0.0001
Age	1.07 (1.01 1.13)	0.013	1.07 (1.03 1.11)	0.001
Sex (female)	1.90 (0.96 3.76)	0.065	1.86 (1.12 3.09)	0.016
Number of medications	1.17 (1.05 1.31)	0.005	1.20 (1.10 1.31)	<0.0001
Change in best eye habitual visual acuity	0.14 (0.02 0.83)	0.03	0.23 (0.06 0.90)	0.03
Change in best eye J_{45}	6.60 (1.36 32.07)	0.019	7.87 (2.26 27.34)	0.001

Adjusted (within the model) and non-adjusted univariate odds ratios (OR) are shown with 95% confidence intervals (CI) and *p*-values. The likelihood ratio chi-squared value for the model was 103.7 ($p < 0.0001$) with pseudo $R^2 = 0.32$.

*Other univariate odds ratios (*p*-value) for factors not included in the final multivariate model included walks outside 0.30 (<0.0001), number of chronic conditions 1.22 (0.03), arthritis 1.58 (0.12), sedative use 2.98 (0.007), best visual acuity post surgery 37.46 (<0.0001), change in anisometropia 1.16 (0.16), change in mean sphere equivalent 1.06 (0.52), change in J_0 2.65 (0.03), Change into multifocal spectacles 1.27 (0.56), Change from multifocal spectacles 1.17 (0.71).

Table 4. The post-operative falls rate of patients who changed either into or out of multifocal spectacles (bifocals and progressives) after cataract surgery compared to those that continued with multifocal wear or continued with their own distance single vision spectacles or no spectacles

Post-op spectacle wear	*N*	Falls rate
Into multifocals	30	30%
Continued with Multifocals	62	23%
Discontinued multifocals	53	15%
Continued with single vision spectacles or without spectacles	133	17%

did not substantially affect the influence of the other variables that we did include. Medical factors such as arthritis were weakly associated with post-operative falls (OR 1.84, CI 0.96–3.52; $p = 0.07$) and post-operative dizziness was strongly associated with falls (OR, 3.34, CI 1.78–6.26; $p < 0.0001$), but pre-operative falls was a much stronger risk factor and acted as a proxy for multifactorial risk factors including age. Post-operative dizziness was retained in the final model (despite a *p*-value of 0.10) as it was an important predictor of interest and may be on the causal pathway between vision changes and falls. Changing into multifocals post surgery increased falls risk significantly (OR = 3.56, CI 1.34–9.43, $p = 0.011$; also see Table 4).

Table 3 indicates that dizziness was present in patients who suffered from dizziness pre-surgery, with increasing age, with the number of medications and with greater changes in oblique astigmatism in the refractive correction. Post-operative dizziness was reduced for patients with larger changes in best eye habitual visual acuity.

Discussion

We found a substantial falls rate both before and after cataract surgery and identified risk factors relating to spectacle management. The multifactorial logistic model with post-operative falls as the outcome measure showed associations with pre-operative falls and changes in spectacle type (into multifocal lens wear; Table 2). There were no significant associations with post-operative VA in the best eye, change in mean spherical equivalent refractive correction, change in astigmatic correction (J_0 or J_{45}), change in anisometropia (all $p > 0.10$) or post-operative activity levels. However, the number with large refractive changes in the operated eye were relatively small (over 4.00D: 33/283, 12%) and Cummings[23] found an increased falls rate with large change in spectacle correction (although the influence of myopic, hyperopic and astigmatic changes were all combined in their report), so further studies with larger numbers of high refractive corrections before surgery may be useful. Activity levels were similar before and after surgery, with 19 participants becoming inactive after surgery when active before surgery. This was typically due to ill health (e.g., arthritis, hip and knee problems). However, of the small number who greatly increased activity after surgery, all ten had no falls before surgery, but four fell after surgery. It is possible that this increased walking about outside the home put the patient at increased risk of falls, particularly while adapting to the new level of vision.[23] However, the numbers in the subsample are small and a larger sample study is required.

The association between falls and changes into or out of multifocal spectacles are shown in Table 4. The falls rate in patients switching into multifocals is double (30%) that of those patients who discontinued multifocal wear (15%). This is in agreement with much of the literature, which suggests that multifocals are a risk factor for falls[26,28] due to blur in the lower visual field (both bifocals and progressive addition), variable areas of vestibulo-ocular reflex gain[35] peripheral distortion in progressive addition lenses and diplopia and image jump at the reading segment edge in bifocals.[27] One area particularly open to change is the correction of ametropia between surgeries. Patients who wore multifocals before first eye surgery and after second eye surgery, but no spectacles in between surgeries (N = 12, falls rate = 33%) would have needed to adapt to not wearing multifocals after first eye surgery (median time of 57 days, IQR 43–81 days; this seems sufficiently long for adaptation to the lack of spectacles to have occurred in most patients)[36] and then re-adapt to wearing them after second eye surgery. This would therefore include two adaptations of the vestibulo-ocular reflex gain, which is variable in multifocals.[35] The number of patients in this comparison are small and this needs further study.

Self-reported dizziness was greater in females and patients with multiple medications (Table 3) and this is similar to earlier findings.[21,37,38] The prevalence of dizziness depends on the population studied and the definition of dizziness used.[21,39–41] Our dizziness prevalence figures are high at 52% pre-operative and 38% post-operative and this likely highlights the wide definition used (anybody indicating dizziness to any one of the 13 questions of the DHIsf) and the older age and poor pre-operative vision of our participants. Given that several studies have shown a strong association between dizziness and reduced quality of life,[40,42] the significant reduction in dizziness due to cataract surgery could be important. The need for cataract surgery is typically determined by the reduction in the desired lifestyle caused by poor vision due to cataract.[43] Although this is typically thought to mean everyday tasks that are reliant on vision, such as driving, seeing faces and reading, this study suggests that dizziness could also be a consideration. Dizziness is multicausal, but even in patients with vestibular disease causing dizziness, appropriate treatment of visual problems can be beneficial.[44] Larger changes in VA (logMAR) reduced the risk of post-operative dizziness (OR 0.14, Table 3) and the improvement in dizziness due to surgery is presumably due to the improvement in VA and possibly linked with improvements in postural stability.[45,46] In addition, greater changes in J_{45}, the vector representing oblique astigmatism, were a risk factor for post-operative dizziness (OR 5.2, Table 3). This is not surprising given that astigmatic correction can lead to distortions in how patients perceive in 3-D space[47,48] and oblique astigmatism is known to produce the greatest problems of distortion[25] and difficulties in adaptation.[36] The strong link between post-operative falls rate and dizziness symptoms (OR, 3.17, $p = 0.002$) was expected and has been suggested by other studies.[19–21] This suggests that those visual and refractive factors influencing dizziness may also have an indirect influence upon falls rates. In this way falls risk may be reduced due to the reduction in dizziness caused by improved VA and may be increased by changes in oblique astigmatic refractive correction.

The study was limited in several ways. The falls data were self-reported recall from the previous 6 months and accurate retrospective assessments of falls are difficult due to poor memory recall of older patients[49] in addition to their self-reported nature and difficulty in defining exactly what constitutes a fall.[31] Monocular VA data were taken from clinical records and it would be preferable to measure binocular VA plus contrast sensitivity, visual field and stereoacuity using standardised protocols. Outdoor activity levels were taken from a simple question about the extent of outdoor activity per month and preference would be for a more detailed questionnaire assessment and/or perhaps pedometer measurements. Finally, the study has highlighted several areas that would benefit from data collection from a larger sample of pre and post-operative cataract surgery patients and these include patients with large ametropic changes and different multifocal wearing patterns of patients undergoing surgery on both eyes.

In summary, this study found that dizziness was reduced by cataract surgery and this was linked with improvements in best eye VA, but increased by changes in oblique astigmatic correction. This needs to be investigated further to determine whether dizziness should be a consideration in the decision of whether to perform cataract surgery. We found no improvement in falls rate with routine cataract surgery. This is probably linked to the relatively good preoperative VAs and possibly to too many patients switching to multifocal spectacle wear post-surgery. This suggests that to maximise the potential for cataract surgery to improve falls rates, patients should be appropriately warned of the potential adaptation problems after surgery, particularly if they had a large change in oblique astigmatism and/or have switched to multifocal wear. In between first and second eye surgeries, multifocal wearers could consider wearing updated multifocals rather than go without spectacles if the intention is to continue multifocal wear post second eye surgery.

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Financial disclosures

No conflicting relationship exists for any author.

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